Helping Massachusetts Municipalities Create a Cleaner Energy Future

COMMONWEALTH OF MASSACHUSETTS

Deval L. Patrick, Governor
Maeve Valley Bartlett, Secretary
Meg Lusardi, Acting Commissioner

Model Permitting and Safety for Solar PV in Massachusetts

Solar PV Permitting and Safety Webinar

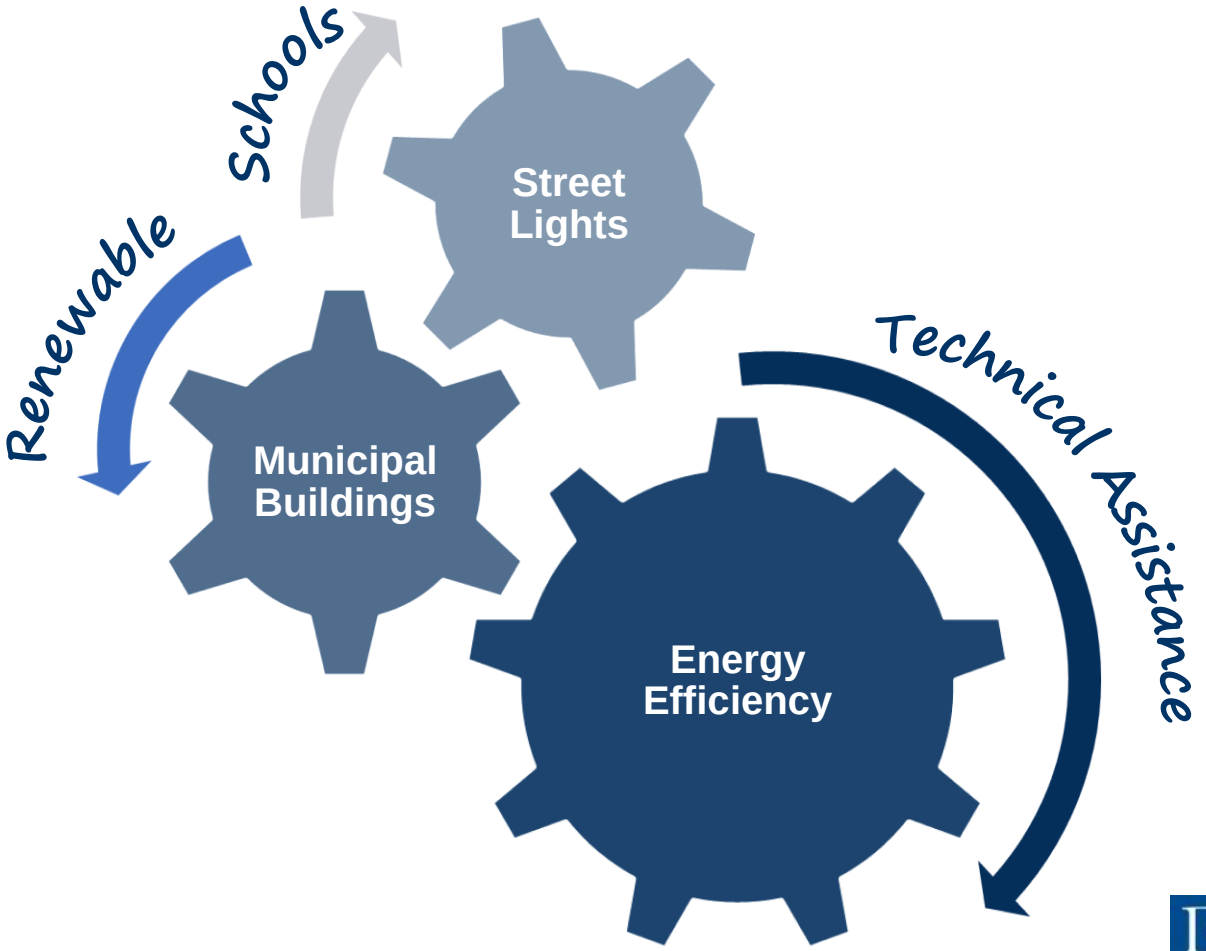
Emma Krause, Rooftop Solar Challenge Coordinator, DOER

Matt Piantedosi, The Cadmus Group

Powered by SunShot U.S. Department of Energy

Green Communities Division

The energy hub for ***all*** Massachusetts cities and towns, not just designated “Green Communities.”



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Outreach - Regional Coordinators

- Regional Coordinators act as direct liaisons with cities and towns on energy efficiency and renewable energy activities
- Located at each of the DEP Regional Offices:

WERO – SPRINGFIELD: Jim Barry
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NERO – WILMINGTON: Joanne Bissetta
Joanne.Bissetta@state.ma.us

CERO – WORCESTER: Kelly Brown
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SERO – LAKEVILLE: Seth Pickering
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Green Communities Division -
Programs & Resources for Municipalities

- Green Communities Designation and Grant Program
- MassEnergyInsight energy tracking and analysis tool
- Municipal Energy Efficiency Program
- Energy Management Services Technical Assistance
- Clean Energy Results Program (CERP)
- Mass Municipal Energy Group (MMEG)
- Website filled with tools & resources: www.mass.gov/energy/greencommunities

Email updates via e-blasts – Sign up by sending an email to:
join-ene-greencommunities@listserv.state.ma.us

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Recording and Presentation

- The webinar is being recorded and will be available on our website in approximately 48 hours at:

  www.mass.gov/energy/greencommunities

- The slide presentation will also be posted at:

  www.mass.gov/energy/greencommunities

- Website and contact information is listed at end of presentation

Training Overview

- Parties building and supporting solar PV development in Massachusetts:
  - Electrical and building inspectors
  - Solar developers
  - Electricians
- Electrical permitting overview & information
- Building permitting overview & information
- Key PV safety concerns and considerations
- Best practices for installing ***and inspecting*** solar PV

Training Overview

- ***Sun to the Grid: Solar PV Inspections***
  - Useful Information to the Permitting Process:
    - Best practices
    - Regulatory requirements
  - Ensure solar PV Systems are:
    - Safe
    - Comply with Massachusetts Requirements
  - DOER Rooftop Solar Challenge:
    - http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/sunshot-rooftop-solar-challenge.html

About The Cadmus Group

- Renewable energy technical and economic experts, with more than a decade experience helping clients to develop renewable energy projects and programs in New England.
- Cadmus performs solar PV quality assurance inspections and design reviews for:
  - Massachusetts Clean Energy Center
  - Rhode Island Renewable Energy Fund
  - New York State Energy Research and Development Authority

- Provide Owner's Agent Technical Assistance
  - Department of Energy Resources Green Communities

Cadmus Solar PV QA Inspections

- Evaluate system compliance with NEC and program technical requirements;
  - A comprehensive inspection of ***all*** components.
  - Random & Targeted (i.e. new installers).
  - Post AHJ Inspection.
  - Prior to receipt of grant/rebate funds.
  - Work with installers, inspectors to resolve issues by providing guidance and education.

About the Trainer

- Matt Piantedosi
  - Senior Associate Engineer & Solar PV Inspector
  - Licensed Master Electrician (MA, NH)
  - Licensed Journeyman Electrician (MA, RI, CT)
  - BS in Electrical Engineering
  - IAEI Paul Revere Chapter Executive Board
  - Inspected over 3 MW of Solar PV:
    - Majority of small, residential PV systems (<12 kW)
    - 6 years inspecting solar PV
    - 14 years working in the trade

Poll Question

- Who is in our audience today?
  a) Building inspector
  b) Electrical inspector
  c) Electrician
  d) Solar installer or developer
  e) Municipal official

PRESCRIPTIVE PROCESS FOR STRUCTURAL APPROVAL OF SMALL SOLAR PV

Prescriptive Process

- Developed as part of the Rooftop Solar Challenge:
  - http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/sunshot-rooftop-solar-challenge.html
- Prescriptive process provides:
  - Guideline for installing and approval of rooftop residential solar.
  - May preclude need for a licensed structural engineer to evaluate rooftop load carrying capacity.
  - Applies to all cities and towns in Massachusetts.
  - Approximately 10-12% of homes (188,000 – 225,000).
- Developed in conjunction with the Dept. of Public Safety and Board of Building Regulation Standards.
- Guidance can be found at http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/permitting-and-structural-review-rsc1.html.

Prescriptive Process

- Prescriptive Process Flowchart:
  - 11 Questions.
  - Requires familiarity with structure under consideration.
  - Requires expertise in construction/ engineering.
- Applies to only Small Residential Solar PV System:
  - Capacity of ≤ 10 kW.
  - Flush-mounted solar PV systems.
  - Range from 3.0 to 3.5 pounds per square foot, comparable to a second layer of roofing singles.
  - One- and Two-Family Residences built after 1976
    - Compliant with MSBC, enacted in 1975.
    - Light-frame wood construction with traditional roof rafters.
  - Arrays installed parallel to roof, ≤ 8 to 12 inches offset.

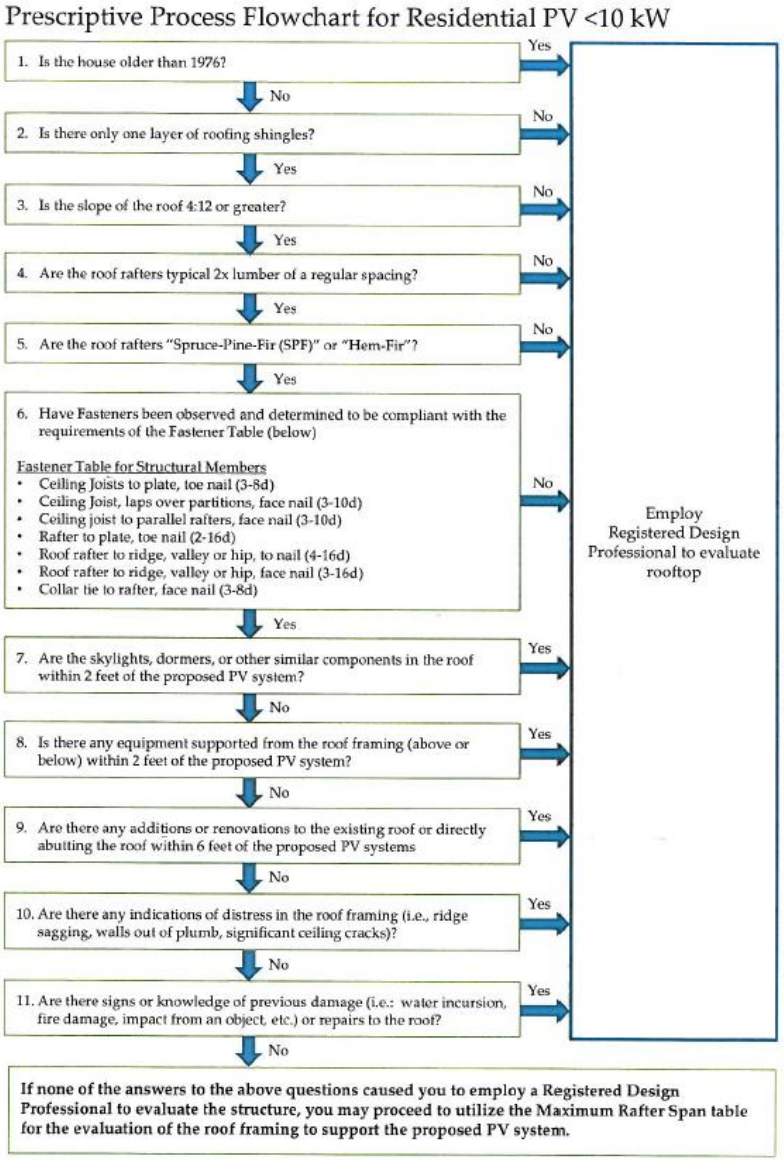
Prescriptive Process

- Expertise required to use the prescriptive process:
  - A *knowledgeable* person in construction/ engineering must become familiar with the structure under consideration.
  - *Knowledgeable* person must be able to differentiate between:
    - Material dimensions, species, or grades sufficiently to be able to properly evaluate the conditions discussed in the prescriptive process.
    - Areas of expertise could include Building Construction, Framing, Carpentry, or Codes.

Prescriptive Process

- Prior to evaluating a structure, familiarize yourself with the ***Prescriptive Process Flowchart for Residential PV <10 KW***
  - 7 Steps
  - 11 Questions
- **Evaluate the structure.**
  - Observe the structural components specified in the Flowchart.
  - Determine if they are in accordance with the stated questions.

Prescriptive Process Flowchart



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Prescriptive Process

- If structural components specified in the Flowchart are ***not observable***, or ***are not in accordance*** with the stated questions,
  - Use a **Registered Design Professional (RDP)** to determine whether there is adequate support for the proposed solar PV system.
- If the structural components specified in the Flowchart are:
  - Observable and in accordance with the Flowchart, and do “not require further evaluation,”
  - Proceed to the **Maximum Rafter Span Table**.

Prescriptive Process Flowchart

1. Is the house older than 1976?
   - **Yes**: Employ a RDP to evaluate rooftop;
   - **No**: Proceed to **Question 2**.
2. Is there only one layer of roofing shingles?
   - **Yes**: Proceed to **Question 3**.
   - **No**: Employ a RDP to evaluate rooftop.
3. Is the slope of the roof 4:12 or greater?
   - **Yes**: Proceed to **Question 4**.
   - **No**: Employ a RDP to evaluate rooftop.

Prescriptive Process Flowchart

4. Are the roof rafters typical 2x lumber of a regular spacing?
   - **Yes**: Proceed to **Question 5**.
   - **No**: Employ a RDP to evaluate rooftop.
5. Are the roof rafters Spruce-Pine-Fir (SPF) or Hem-Fir?
   - **Yes**: Proceed to **Question 6**.
   - **No**: Employ a RDP to evaluate rooftop.

Prescriptive Process Flowchart

6. Have fasteners been observed and determined to be compliant with the requirements of the Fastener Table?
   - **Yes**: Proceed to **Question 7**.
   - **No**: Employ a RDP to evaluate rooftop.

Fastener Table for Structural Members

- Ceiling Joists to plate, toe nail (3-8d)
- Ceiling Joist, laps over partitions, face nail (3-10d)
- Ceiling joist to parallel rafters, face nail (3-10d)
- Rafters to plate, toe nail (2-16d)
- Roof rafters to ridge, valley or hip, to nail (4-16d)
- Roof rafter to ridge, valley or hip, face nail (3-16d)
- Collar tie to rafter, face nail (3-8d)

Prescriptive Process Flowchart

7. Are the skylights, dormers, or other similar components in the roof within 2 feet of the proposed PV system?
   - **Yes**: Employ a RDP to evaluate rooftop;
   - **No**: Proceed to **Question 8**.
8. Is there any equipment supported form the roof framing (above or below) within 2 feet of the proposed PV system?
   - **Yes**: Employ a RDP to evaluate rooftop;
   - **No**: Proceed to **Question 9**.

Prescriptive Process Flowchart

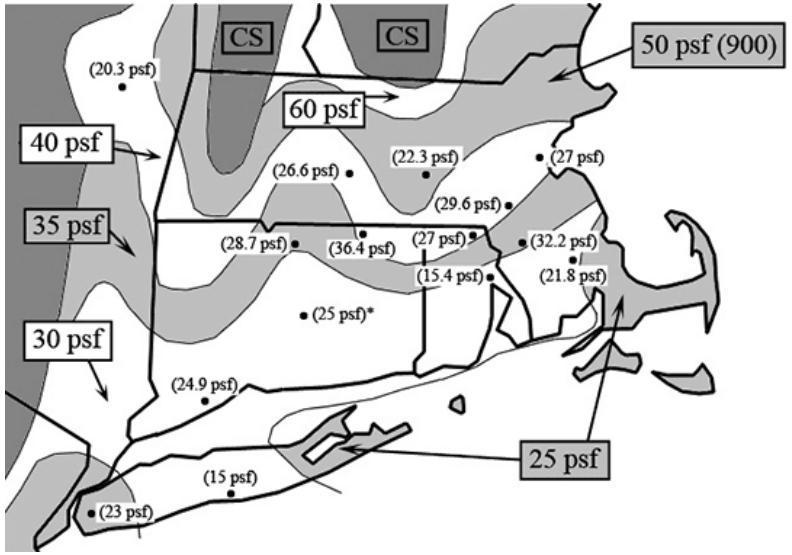
9. Are there any additions or renovations to the existing roof or directly abutting the roof within 6 feet of the proposed PV system?
   - **Yes**: Employ a RDP to evaluate rooftop;
   - **No**: Proceed to **Question 10**.
10. Are there any indications of distress of the roof framing (i.e. ridge sagging, walls out of plumb, significant ceiling cracks?)
   - **Yes**: Employ a RDP to evaluate rooftop;
   - **No**: Proceed to **Question 11**.

Prescriptive Process Flowchart

11. Are there signs of knowledge of previous damage (i.e. water incursion, fire damage, impacts from an object, etc.) or repairs to the roof?
    - **Yes**: Employ a RDP to evaluate rooftop;
    - **No**: If no answers result in the need for an RDP to evaluate the structure, you may proceed to utilized the **Maximum Rafter Span** table for the evaluation of the roof framing to support the proposed solar PV system.

Prescriptive Process

- Before using the Maximum Rafter Span Table,
  - Determine the ***ground snow load requirements*** (***30, 40, or 50 psf***) for the structure based on the Snow Load Zones identified in the Massachusetts Building Code.
  - Identify the structure's ***rafter species, grade, size, and spacing***.



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Prescriptive Process

- Use the Maximum Rafter Span Table to:
  - Identify the maximum span for the structure framing that can support the proposed solar PV system.
  - If the structure's existing span is ***less than the maximum span listed in the table***, the solar PV system may be installed on the roof *without further structural analysis*.

Maximum Rafter Spans

Maximum Rafter Spans (for non-cathedral ceilings)

DL = 10 psf, Max PV weight = 3.5 psf, max PV supports at 2 x Rafter spacing (alternate rafter loading)

			12" RAFTER SPACING				16" RAFTER SPACING				24" RAFTER SPACING			
			2x6	2x8	2x10	2x12	2x6	2x8	2x10	2x12	2x6	2x8	2x10	2x12
P_g = 30 psf	Hem-Fir	SS	13' - 8"	18' - 0"	23' - 0"	28' - 0"	12' - 5"	16' - 5"	20' - 11"	25' - 5"	10' - 6"	13' - 11"	17' - 9"	21' - 7"
	Hem-Fir	#1	12' - 5"	16' - 5"	20' - 11"	25' - 5"	10' - 9"	14' - 2"	18' - 1"	22' - 0"	8' - 9"	11' - 7"	14' - 9"	18' - 0"
	Hem-Fir	#2	11' - 7"	15' - 4"	19' - 6"	23' - 9"	10' - 0"	13' - 3"	16' - 11"	20' - 7"	8' - 2"	10' - 10"	13' - 10"	16' - 10"
	Hem-Fir	#3	8' - 11"	11' - 9"	15' - 0"	18' - 3"	7' - 8"	10' - 2"	13' - 0"	15' - 9"	6' - 3"	8' - 3"	10' - 7"	12' - 10"
	Spruce-Pine-Fir	SS	13' - 5"	17' - 8"	22' - 6"	27' - 5"	12' - 2"	16' - 0"	20' - 6"	24' - 11"	9' - 11"	13' - 1"	16' - 9"	20' - 4"
	Spruce-Pine-Fir	#1	11' - 9"	15' - 6"	19' - 10"	24' - 1"	10' - 2"	13' - 5"	17' - 2"	20' - 11"	8' - 4"	11' - 0"	14' - 0"	17' - 0"
	Spruce-Pine-Fir	#2	11' - 9"	15' - 6"	19' - 10"	24' - 1"	10' - 2"	13' - 5"	17' - 2"	20' - 11"	8' - 4"	11' - 0"	14' - 0"	17' - 0"
	Spruce-Pine-Fir	#3	8' - 11"	11' - 9"	15' - 0"	18' - 3"	7' - 8"	10' - 2"	13' - 0"	15' - 9"	6' - 3"	8' - 3"	10' - 7"	12' - 10"
P_g = 40 psf	Hem-Fir	SS	12' - 10"	16' - 11"	21' - 7"	26' - 3"	11' - 8"	15' - 4"	19' - 7"	23' - 10"	9' - 7"	12' - 7"	16' - 1"	19' - 7"
	Hem-Fir	#1	11' - 3"	14' - 10"	19' - 0"	23' - 1"	9' - 9"	12' - 10"	16' - 5"	20' - 0"	8' - 0"	10' - 6"	13' - 5"	16' - 4"
	Hem-Fir	#2	10' - 6"	13' - 11"	17' - 9"	21' - 7"	9' - 1"	12' - 0"	15' - 4"	18' - 8"	7' - 5"	9' - 10"	12' - 6"	15' - 3"
	Hem-Fir	#3	8' - 1"	10' - 8"	13' - 7"	16' - 6"	7' - 0"	9' - 2"	11' - 9"	14' - 4"	5' - 8"	7' - 6"	9' - 7"	11' - 8"
	Spruce-Pine-Fir	SS	12' - 7"	16' - 6"	21' - 1"	25' - 8"	11' - 1"	14' - 7"	18' - 7"	22' - 8"	9' - 0"	11' - 11"	15' - 2"	18' - 6"
	Spruce-Pine-Fir	#1	10' - 8"	14' - 1"	18' - 0"	21' - 11"	9' - 3"	12' - 2"	15' - 7"	18' - 11"	7' - 6"	9' - 11"	12' - 8"	15' - 6"
	Spruce-Pine-Fir	#2	10' - 8"	14' - 1"	18' - 0"	21' - 11"	9' - 3"	12' - 2"	15' - 7"	18' - 11"	7' - 6"	9' - 11"	12' - 8"	15' - 6"
	Spruce-Pine-Fir	#3	8' - 1"	10' - 8"	13' - 7"	16' - 6"	7' - 0"	9' - 2"	11' - 9"	14' - 4"	5' - 8"	7' - 6"	9' - 7"	11' - 8"
P_g = 50 psf	Hem-Fir	SS	12' - 2"	16' - 0"	20' - 5"	24' - 10"	10' - 9"	14' - 3"	18' - 2"	22' - 1"	8' - 10"	11' - 7"	14' - 10"	18' - 0"
	Hem-Fir	#1	10' - 5"	13' - 9"	17' - 6"	21' - 4"	9' - 0"	11' - 10"	15' - 2"	18' - 5"	7' - 4"	9' - 8"	12' - 4"	15' - 1"
	Hem-Fir	#2	9' - 8"	12' - 10"	16' - 4"	19' - 11"	8' - 5"	11' - 1"	14' - 2"	17' - 3"	6' - 10"	9' - 0"	11' - 7"	14' - 1"
	Hem-Fir	#3	7' - 5"	9' - 10"	12' - 6"	15' - 3"	6' - 5"	8' - 6"	10' - 10"	13' - 2"	5' - 3"	6' - 11"	8' - 10"	10' - 9"
	Spruce-Pine-Fir	SS	11' - 9"	15' - 6"	19' - 10"	24' - 1"	10' - 2"	13' - 5"	17' - 2"	20' - 11"	8' - 4"	11' - 0"	14' - 0"	17' - 1"
	Spruce-Pine-Fir	#1	9' - 10"	13' - 0"	16' - 7"	20' - 2"	8' - 6"	11' - 3"	14' - 4"	17' - 6"	6' - 11"	9' - 2"	11' - 9"	14' - 3"
	Spruce-Pine-Fir	#2	9' - 10"	13' - 0"	16' - 7"	20' - 2"	8' - 6"	11' - 3"	14' - 4"	17' - 6"	6' - 11"	9' - 2"	11' - 9"	14' - 3"
	Spruce-Pine-Fir	#3	7' - 5"	9' - 10"	12' - 6"	15' - 3"	6' - 5"	8' - 6"	10' - 10"	13' - 2"	5' - 3"	6' - 11"	8' - 10"	10' - 9"

Notes and Assumptions for Use of Above Table

1. Prior to use of this Table, comply with the Prescriptive Process Flowchart for Residential PV <10 kW.
2. This Table to be utilized by appropriately knowledgeable engineering or construction individuals.
3. Use of this table assumes construction is Code Compliant, i.e., collar ties exist at appropriate spacing, rafters are correctly located on opposing sides of ridge beam.
4. Actual spans exceeding the Table values may be reduced by installing rafter braces to appropriate bearing wall locations, employ a Registered Design Professional (RDP) for proper details.
5. Ground Snow Loads (P_g) based on 780 CMR 58.00.
6. Allowable stress design based on NDS-2005, maximum total load deflection limited to L/180.
7. PV panels installed parallel to the roof plane and the distance between the roof covering and bottom of the PV panel is ≤ 12".

Prescriptive Process

- If the structure's existing span ***exceeds the maximum span*** identified in the Maximum Rafter Span Table,
  - Use an RDP to identify other qualifying structural conditions, or recommend bracing or other improvements to the structure, which could enable the proposed solar PV system to be installed.

Prescriptive Process

- Additional weight from a PV system ***requires an increase to roof framing support***:
  - Increased from building code specified snow load at time of construction to the sum of:
    - The proposed solar PV system weight.
    - Increased effects of the snow load due to the inclusion of the coefficient of temperature.
    - Possible increases in the snow load requirements in the ***current*** building code.
  - These factors can increase the roof framing support requirements by 20%.
  - The prescriptive process is designed to incorporate this increase

Questions??

Solar Permitting and Structural Review:
http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/solar-permitting-and-structural-review-rsc2.html

Technical Contacts

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Tom Riley at Thomas.riley@state.ma.us
phone: (617) 826-5250

Feedback/Questions

Emma Krause at emma.krause@state.ma.us
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MODEL ELECTRICAL INSTALLATION AND PERMITTING REQUIREMENTS FOR PV SYSTEMS

Model Electrical Requirements

- Guide for installers & wiring officials
  - **Supplement** to the Uniform Application for Permit to Perform Electrical Work.
  - Information on by-law requirements.
  - Best practices.
- Goal: Ensure that solar PV systems:
  - Are installed safely.
  - Comply with Massachusetts' code requirements.
- DOER Rooftop Solar Challenge: http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/solar-permitting-and-structural-review-rsc2.html

Model Electrical Requirements

- MGL c. 143 § 3L requires individuals installing electrical wiring to:
  - Give notice on start and completion of electrical work.
  - Notice of commencement must be received within 5 days of starting work.
  - AHJ is required to approve/disapprove work within 5 days of notice of completion.
    - If disapproval is given; applicable sections of Massachusetts Electrical Code (527 CMR 12) must be provided.
- Installation of PV components must be by ***Massachusetts-licensed*** electricians per the ratio requirements specified in MGL c. 141 § 1.
  - One-to-One Ratio
    - Licensed Electrician per Apprentice
  - Master license required for companies employing electricians
  - Guidance Memo 13-01


Courtesy of Mass. Electric Construction Co.

MA Licensing Requirements Guidance Memo 13-01

- Massachusetts Electricians Licensing requirements relating to the installation of P.V. (photovoltaic) systems
  - The Board of State Examiners of Electricians
    - http://www.mass.gov/ocabr/licensee/dpl-boards/el/
  - Solar PV systems often require work from many trades.
- Court Ruling - C.A. No. 10-3408:
  - General Contractors (GCs) may advertise and contract to install solar PV Systems:
    - GCs must subcontract to licensed electrician.
    - Advertising to install solar PV is not subject to regulation by the Board.
  - http://www.mass.gov/ocabr/docs/dpl/boards/el/carroll-decision.pdf
- Board Guidance Issued (Guidance Memo 13-01)
  - Solar PV system is defined by 527 CMR 12.00, Article 690.2.
  - Electrical work consists of installing elements which carry electricity, or are part of an equipment grounding system.
  - Non-electrical work could include roof penetrations or attaching footers.
  - Many variations of system components, check with AHJ with questions concerning licensing.
  - http://www.mass.gov/ocabr/licensee/dpl-boards/el/regulations/board-policies/guidance-memo-pv-installation.html

Model Electrical Requirements

- Key Guidance for ***Installers***:
  - Electrical work ***must not be covered, concealed, modified, or energized*** until approved by the AHJ.
    - If covered before AHJ approval, the inspector may require you to remove modules or other elements to provide access during an inspection
  - Applicant listed on the Uniform Permit Application ***must notify the AHJ when work is complete***.
  - Responsible party (applicant, designee) ***must be onsite during the inspection***.
  - Multiple inspections may be required in various phases, at the discretion of the AHJ.

Example of an installation that may require a rough inspection before the installation of PV modules.

Model Electrical Requirements

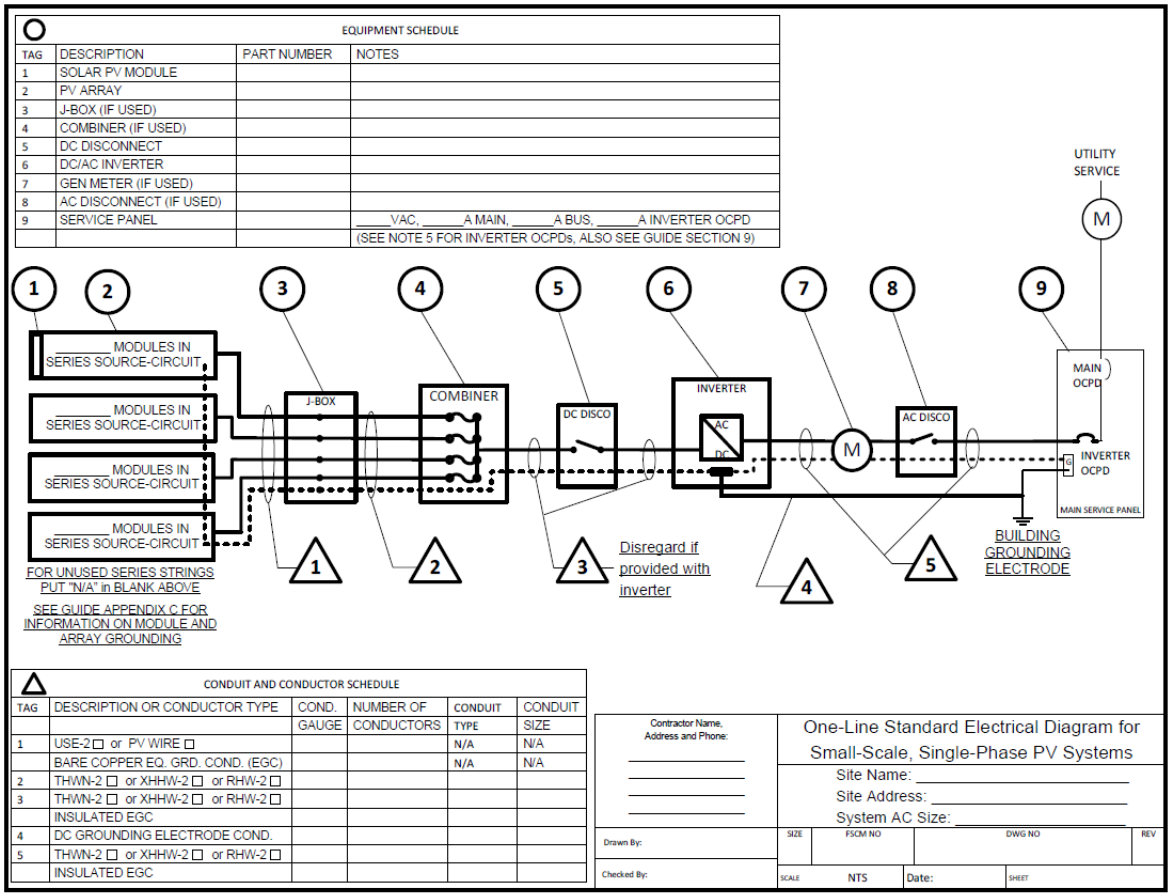
- Key Recommendations for ***Installers***:
  - Establish open communications with the AHJ.
  - ***Contact the AHJ prior to commencing work:***
    - Plan reviews may be necessary and should be completed before beginning work.
  - Contact the ***local fire department*** to confirm a solar PV system is being installed in their jurisdiction.

Model Electrical Requirements

- Key Guidance for ***Inspectors***:
  - In addition to the Uniform Permit Application, AHJs may require (not limited to):
    - One-Line Electrical Drawing
    - Site Plan
    - Specifications Sheets

Application Requirements for Solar PV

- One-Line Electrical Drawing



EQUIPMENT SCHEDULE

TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE		
2	PV ARRAY		
3	J-BOX (IF USED)		
4	COMBINER (IF USED)		
5	DC DISCONNECT		
6	DC/AC INVERTER		
7	GEN METER (IF USED)		
8	AC DISCONNECT (IF USED)		
9	SERVICE PANEL		____VAC, _____A MAIN, _____A BUS, _____A INVERTER OCPD
			(SEE NOTE 5 FOR INVERTER OCPDs, ALSO SEE GUIDE SECTION 9)

CONDUIT AND CONDUCTOR SCHEDULE

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 ☐ or PV WIRE ☐			N/A	N/A
	BARE COPPER EQ. GRD. COND. (EGC)			N/A	N/A
2	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
3	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
	INSULATED EGC				
4	DC GROUNDING ELECTRODE COND.				
5	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
	INSULATED EGC				

Contractor Name, Address and Phone:

One-Line Standard Electrical Diagram for Small-Scale, Single-Phase PV Systems

Site Name: _____

Site Address: _____

System AC Size: _____

Drawn By: | SIZE | FSCM NO | DWG NO | REV

Checked By: | SCALE NTS | Date: | SHEET

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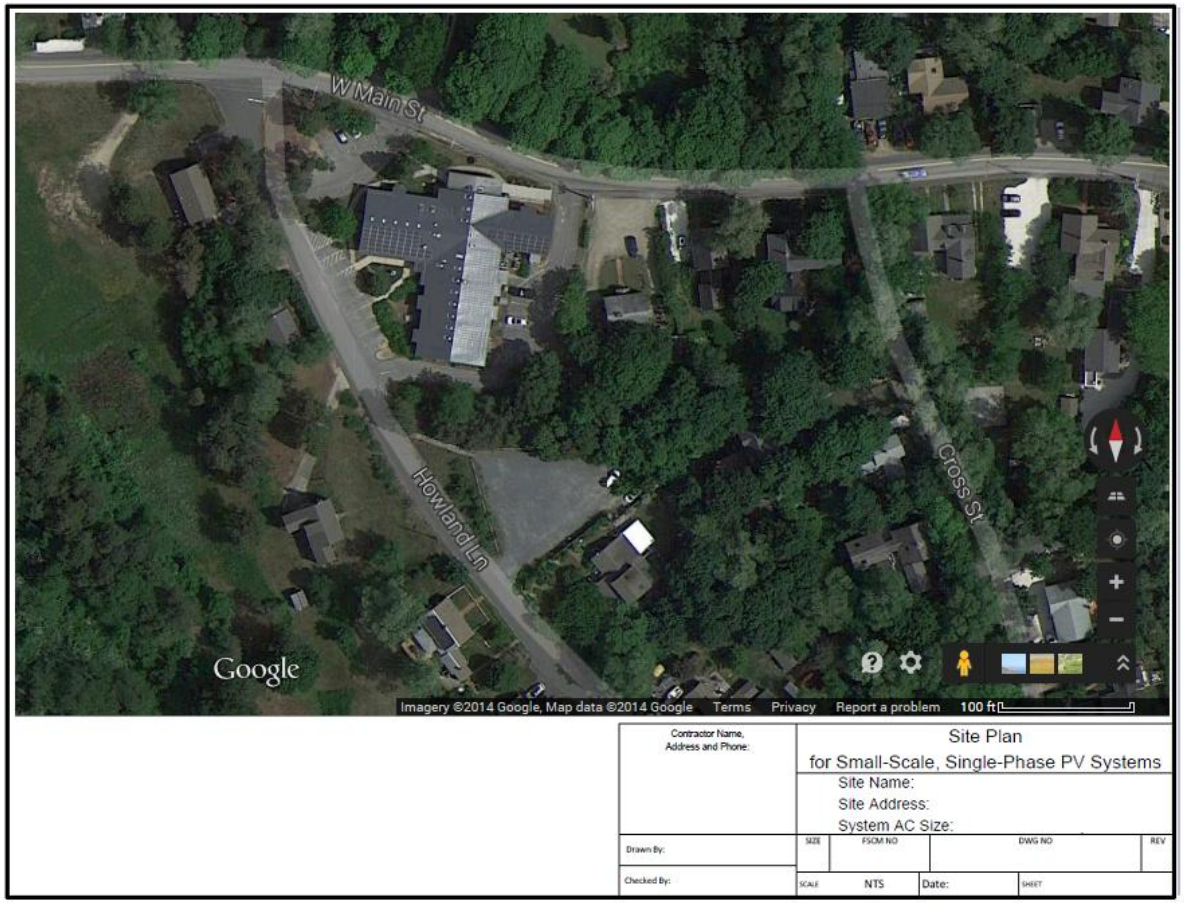
Application Requirements for Solar PV

- Site Plan Drawing



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Application Requirements for Solar PV

- Manufacturers specification sheets
  - Solar PV Modules
  - Racking
  - Inverter

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Poll Question

- How likely are you to use the prescriptive process and/or solar PV guidance document?
  a) Very likely
  b) Somewhat likely
  c) Not likely

INSPECTING SOLAR PV:
PRACTICAL FIELD ADVICE

Practical Field Advice

- Prior to commencement of work:
  - Provide ***Letter from the Inspector***
  - Require Installation Documentation
  - Understand solar PV-specific requirements:
    - Common confusion
    - PV Violations and Safety Concerns
    - MassCEC's Minimum Technical Requirements
- Inspecting Solar PV:
  - Top Issues at the Array, Inverter, and Interconnection to the Grid
- *The inspection process and procedures are evolving alongside the industry –to ensure safe installation practices are used.*

Prior: Letter from the Inspector

- Instructions to supplement the Uniform Application for Permit to Perform Electrical Work
  - Intended for systems ≤10 kW
  - Requires listed components
  - Requires data sheets for all components

CITY OF SOMERVILLE, MASSACHUSETTS
OFFICE OF STRATEGIC PLANNING & COMMUNITY DEVELOPMENT
JOSEPH A. CURTATONE
MAYOR

INSPECTIONAL SERVICES DIVISION

RE: Installation of Solar Photovoltaic Systems

When applying for an electrical permit for a solar PV system of (10 kW or less) in addition to the standard electrical application, please include the expedited application form or equivalent available at www.solarabcs.org. You will find all the information necessary to complete the form in its entirety here.

All equipment, devices, and fittings shall be listed and labeled by a Nationally Recognized Testing Laboratory (NRTL) and installed according to the manufacturer's installation instructions, in accordance with Article 110.3 (B) of the National Electrical Code.

You will also be required to provide specification sheets and installation manuals (if available) for all manufactured components including, but not limited to, PV modules, inverters, combiner boxes, disconnects, mounting systems, and grounding and bonding systems, with application .

Before completing plans for a PV system, the installer must understand that most PV systems will become part of the existing electrical service including the grounding electrode system. The existing systems, because of the addition of the PV system, code changes, or as a result of normal wear issues since it was installed, may no longer be compliant or safe. Additions or modifications under these conditions could create a code violation.

The applicant will be responsible for making the existing service and its grounding electrode system safe and in compliance with the current edition of the Massachusetts Electrical Code, before connection to the PV system is made.

Somerville requires prior notice before installation so that an in progress inspection can be scheduled.

For inaccessible roof mounted installations, please provide clear photos of mounting system, module frame grounding, cable management and protection method, fittings at conduits and boxes, all conductor terminations, combiner boxes with cover removed, all labels including manufacturer labels at the modules and micro-inverters (if installed).

PV system inspections require extended review; request for inspections along with required pictures as noted above must be received 72 hours before inspection will be scheduled.

John Power
Chief Electrical Inspector,
(617) 625-6600 x 5634

DPW BUILDING • 1 FRANEY ROAD • SOMERVILLE, MASSACHUSETTS 02145
(617) 625-6600 EXT. 5600 • TTY: (866) 808-4851 • FAX: (617) 666-2624
www.somervillema.gov

ONE CALL to CITY HALL 3 1 1 SOMERVILLE

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Prior: Letter from the Inspector

- Solar PV system will be interconnected with the existing electrical service and rely on the grounding electrode system:
  - Existing grounding electrode system may not meet the current code requirements.
- Solar PV installation requires “rough” and “final” inspections.

Installation Documentation

- To ***supplement*** an onsite inspection, detailed photos should be available for all:
  - Module mounting system
  - Module frame grounding
  - Rooftop grounding/bonding methods
  - Cable management and protection method
  - Conduit/enclosure fittings
  - All conductor terminations
  - Interior of all enclosures
- Evidence associating photos with site

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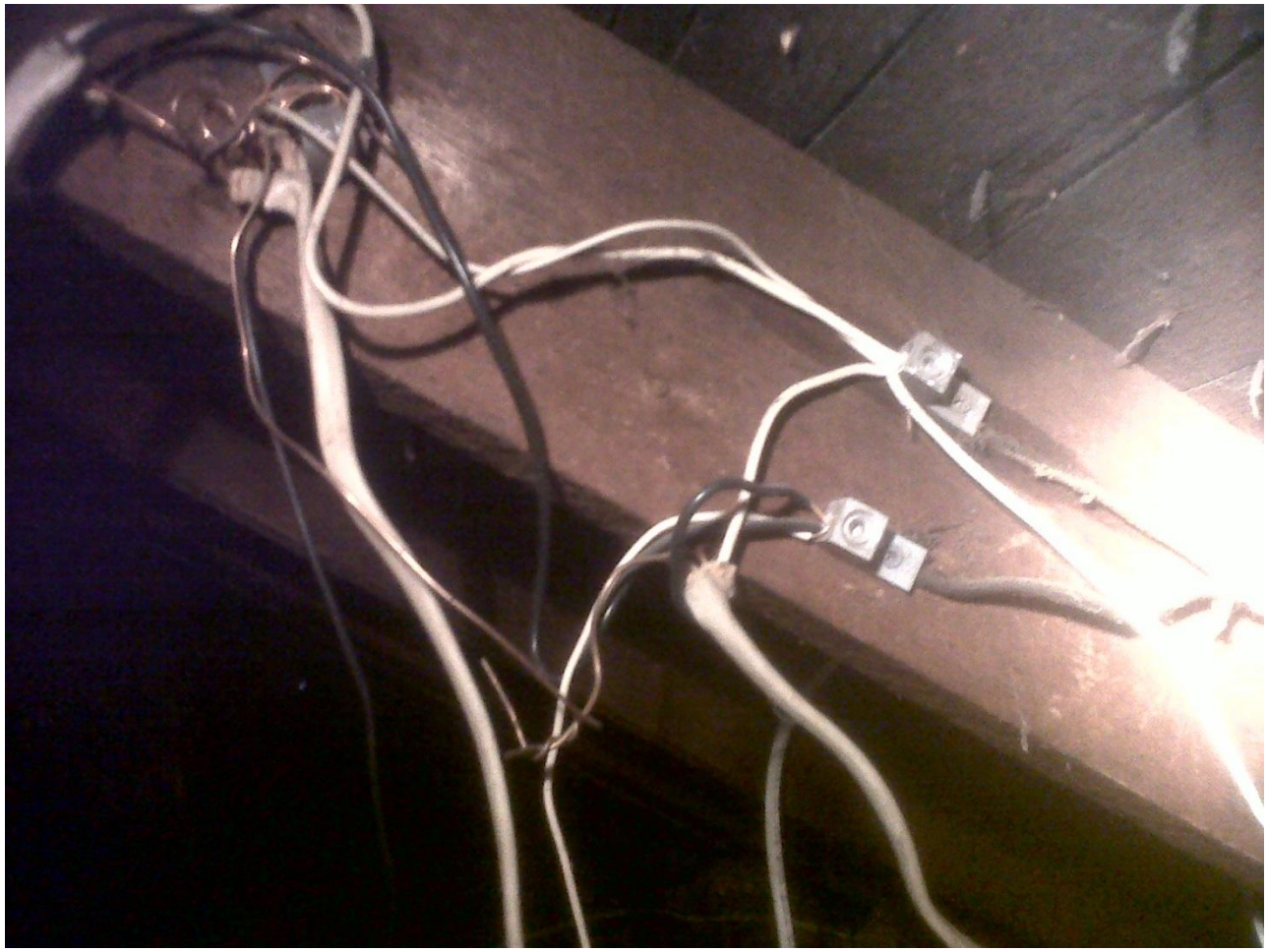
Common PV Safety Concerns



PV Violations & Inspection Techniques

- The following slides:
  - Intended to provide a high-level review of PV system inspections
  - Outline the most common code compliance issues
  - Review specific areas of misinterpretation
  - Future in-depth PV trainings may be available
    - Continuing education providers
    - Local trade associations
    - Other grant programs

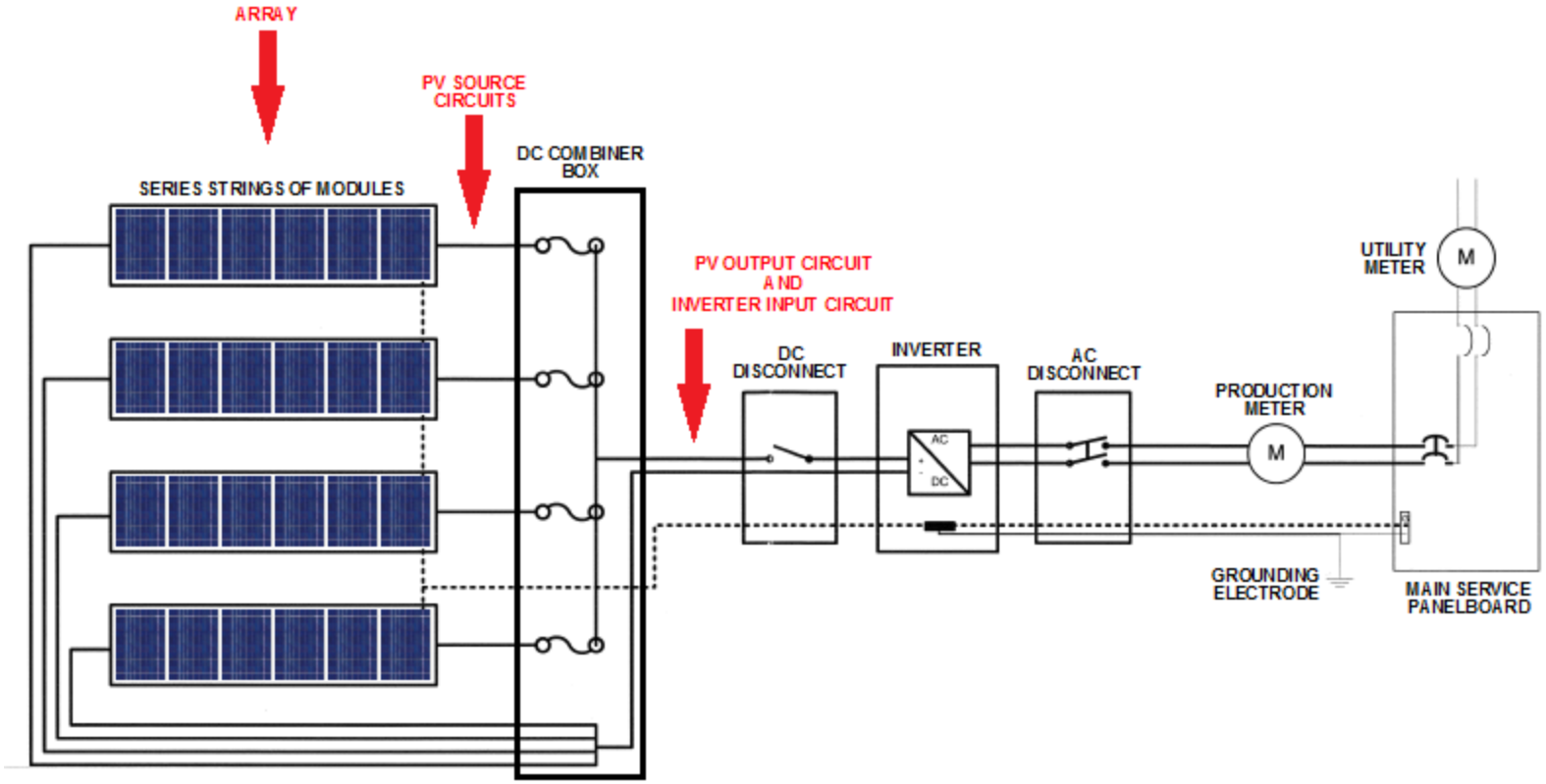
2014 National Electrical Code

Key Articles to Solar PV

- **Article 250**
  - Grounding and Bonding
- **Article 300**
  - Wiring Methods
- **Article 690**
  - Solar Photovoltaic (PV) Systems
- **Article 705**
  - Interconnected Electric Power Production Sources

Utility-Interactive Central Inverter System

NEC Article 690.2



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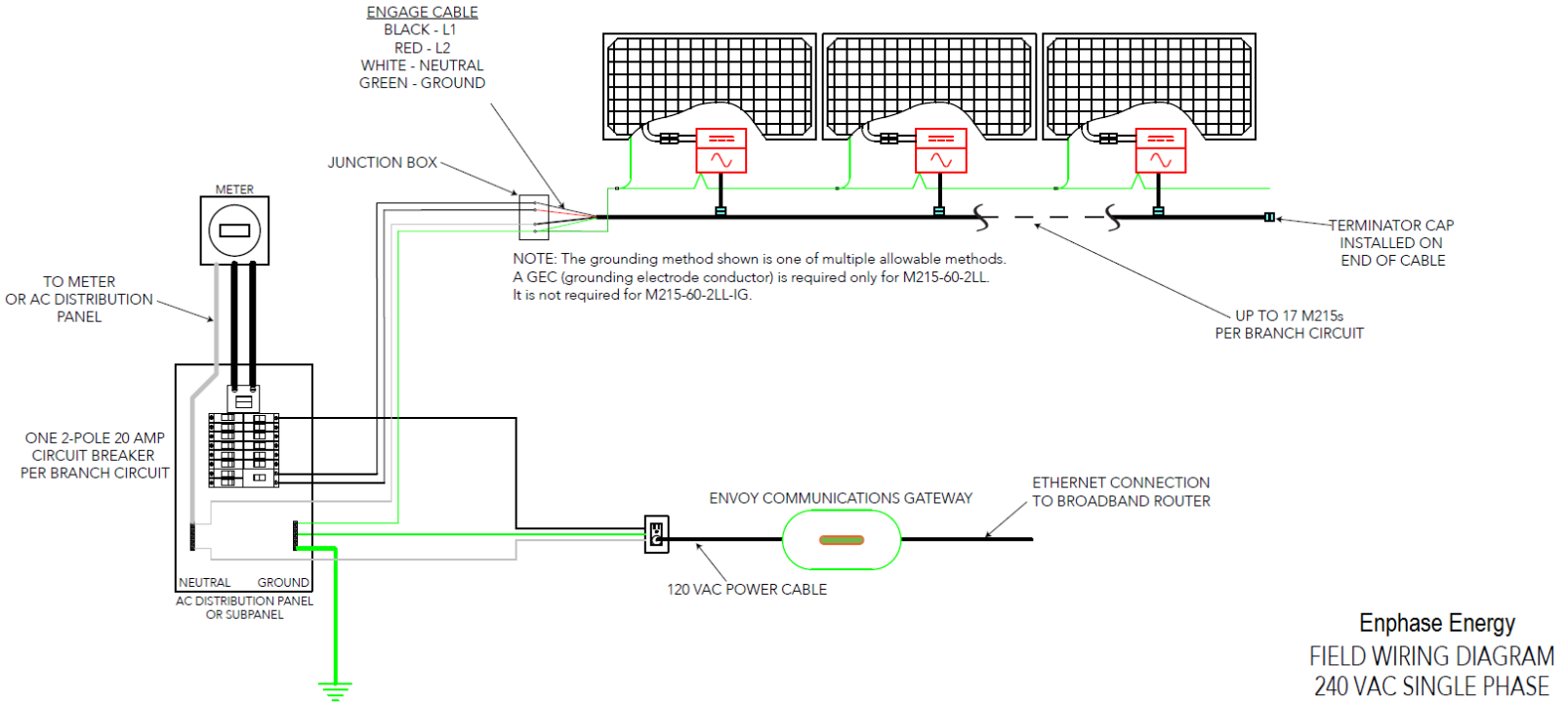
Utility-Interactive AC (Microinverter) System



Enphase Energy
FIELD WIRING DIAGRAM
240 VAC SINGLE PHASE

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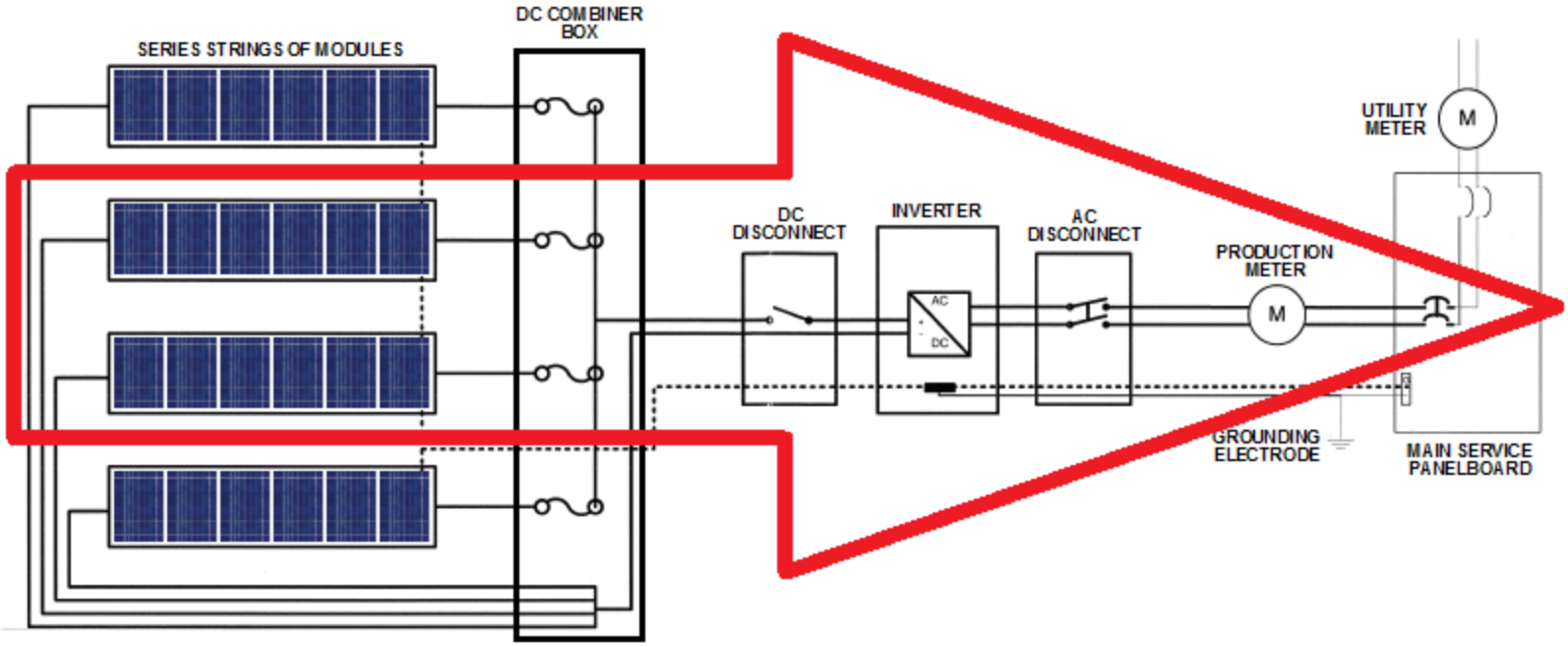

TOP PV VIOLATIONS & INSPECTION TECHNIQUES

FROM THE SUN TO THE GRID…

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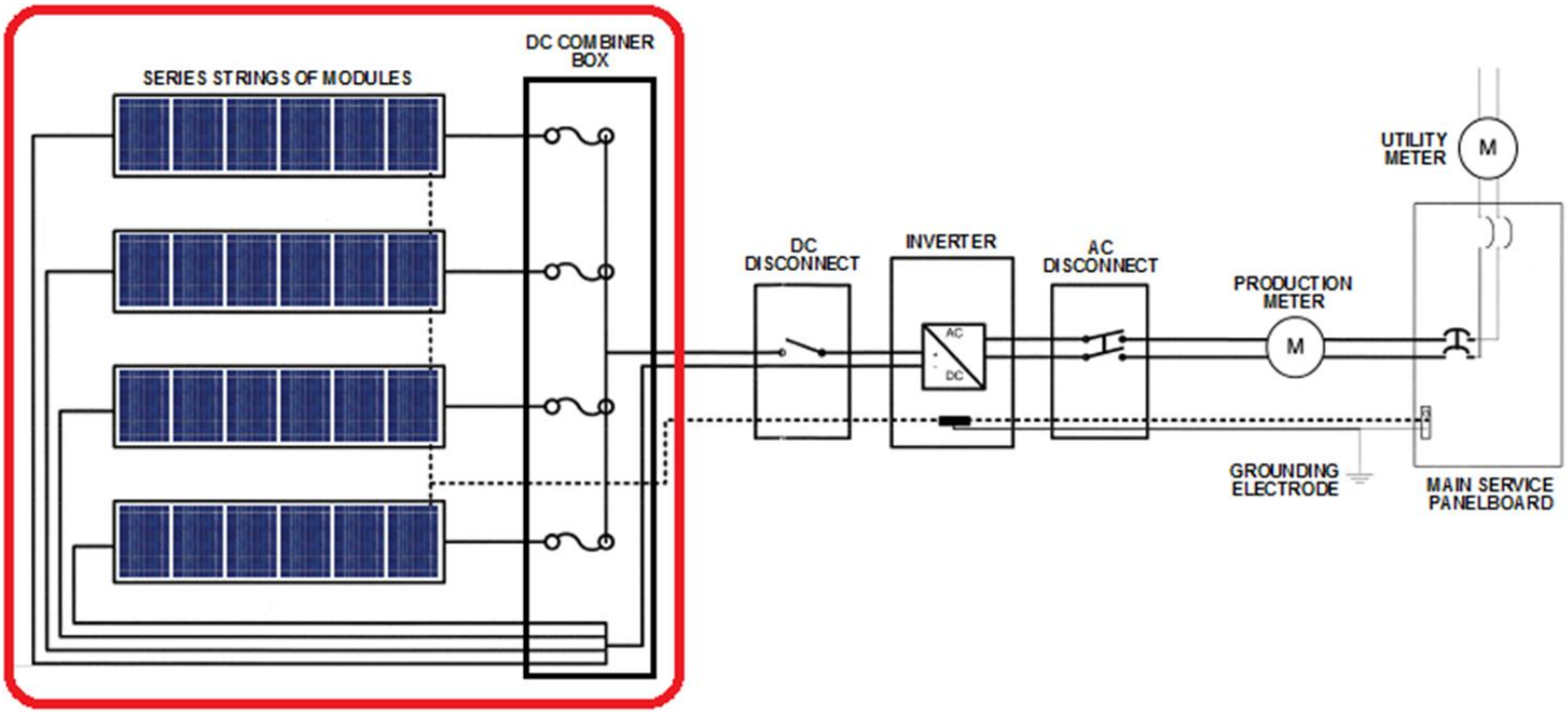
Array Violations



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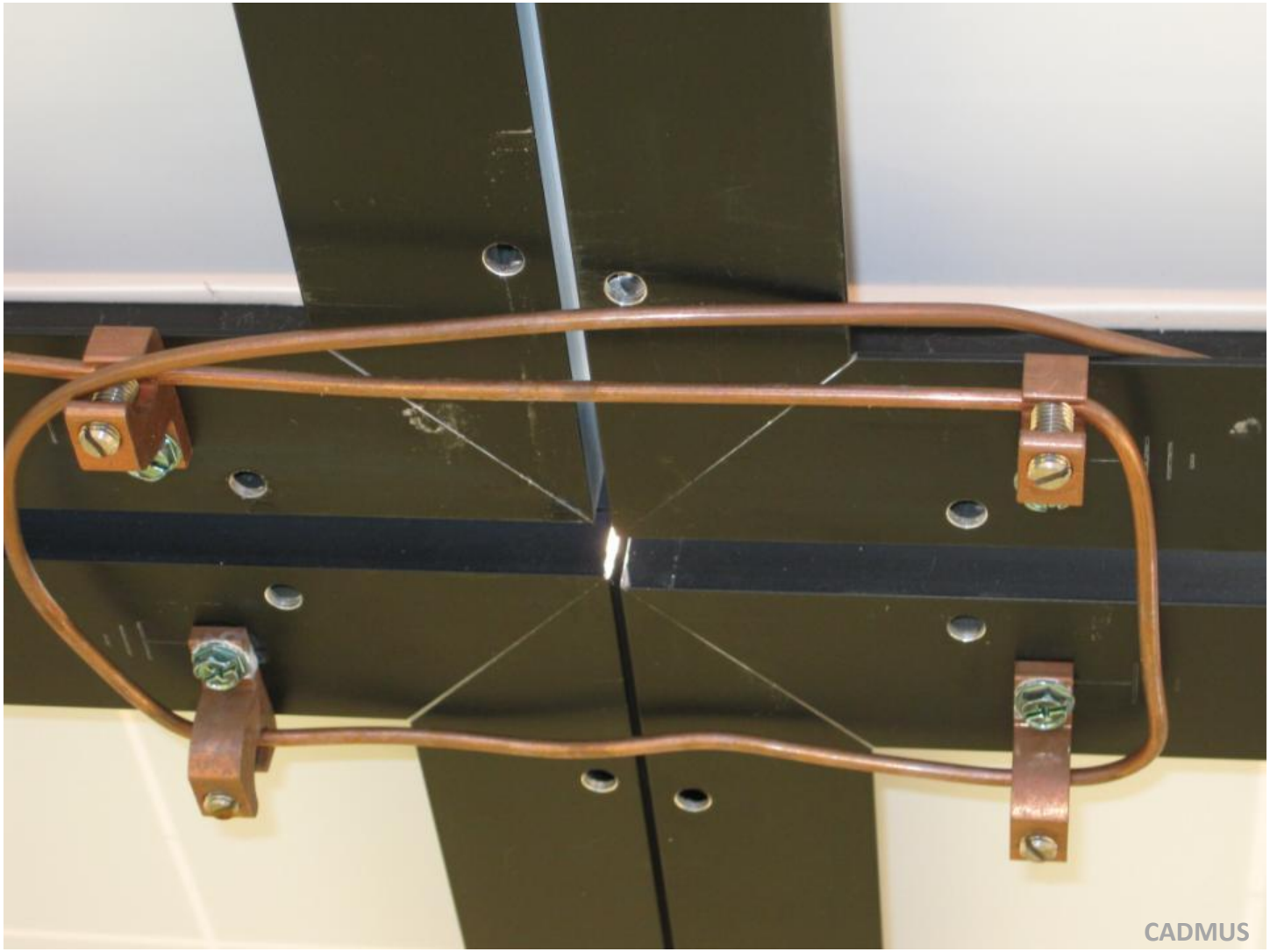
Common Array Violations

- Array grounding insufficient or missing
  - Grounding must be in accordance with 690.43
    - All non-current-carrying metal parts must be grounded → 250.134 or 250.136(A)
  - Lugs at array must be listed for outdoor use
    - Typically direct-burial "DB"
    - Tin-plated copper

  - 690.46 → 250.120(C) – Protection smaller than #6 AWG equipment grounding conductor



Copper lugs and improper grounding screws on aluminum module frames.

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Lay-in lug not listed for outdoor use.

The Right Way…

Tin-plated DB copper lugs on aluminum module frames

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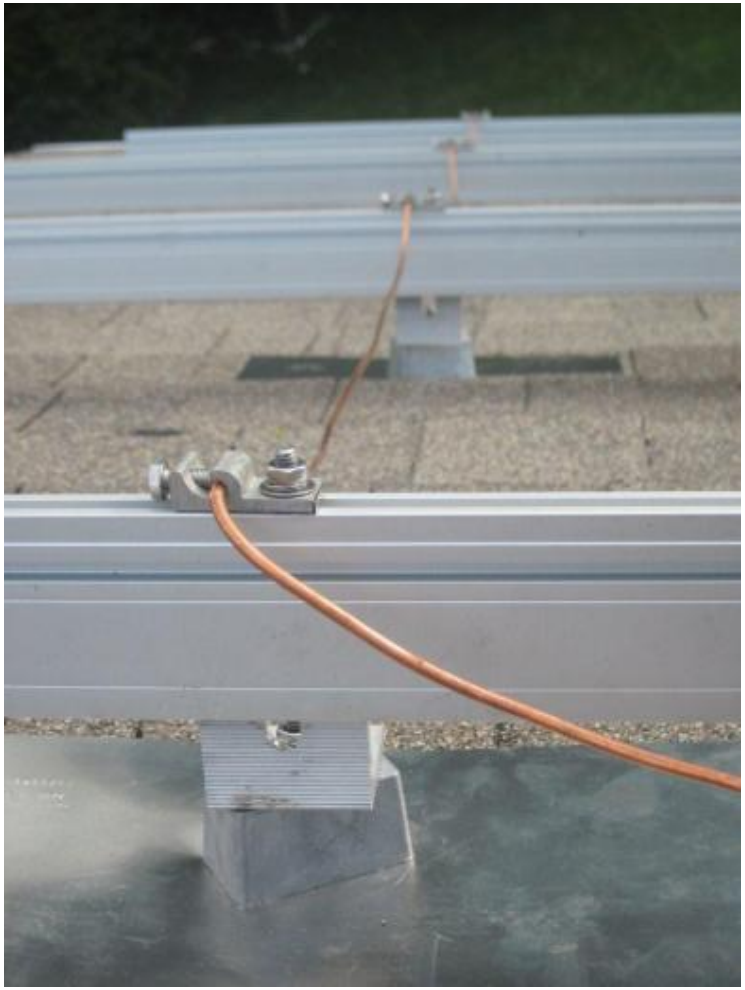
The Right Way…



Listed rail grounding method

WEEB listed to bond module frame

Common Array Violations

- DC conductors at array not properly supported and protected
  - Conductors shall be protected against physical damage (including those beneath array)
  - Articles:
    - 300.4
    - 338.10(B)(4)(b)
    - 334.30
    - 338.12(A)(1)

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The Right Way…

PV conductors free from physical damage.

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The Right Way…

PV conductors supported from roof surface.

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Readily Accessible Locations
NEC Article 690.31(A)

- Ground-mount arrays
  - In readily accessible locations, conductors **shall be guarded** or installed in a raceway

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PV conductors in readily accessible locations shall be installed in a raceway.

PV conductors in readily accessible locations shall be guarded or installed in a raceway.

The Right Way…

Readily accessible PV conductors properly guarded.

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The Right Way…

Readily accessible PV conductors properly guarded.

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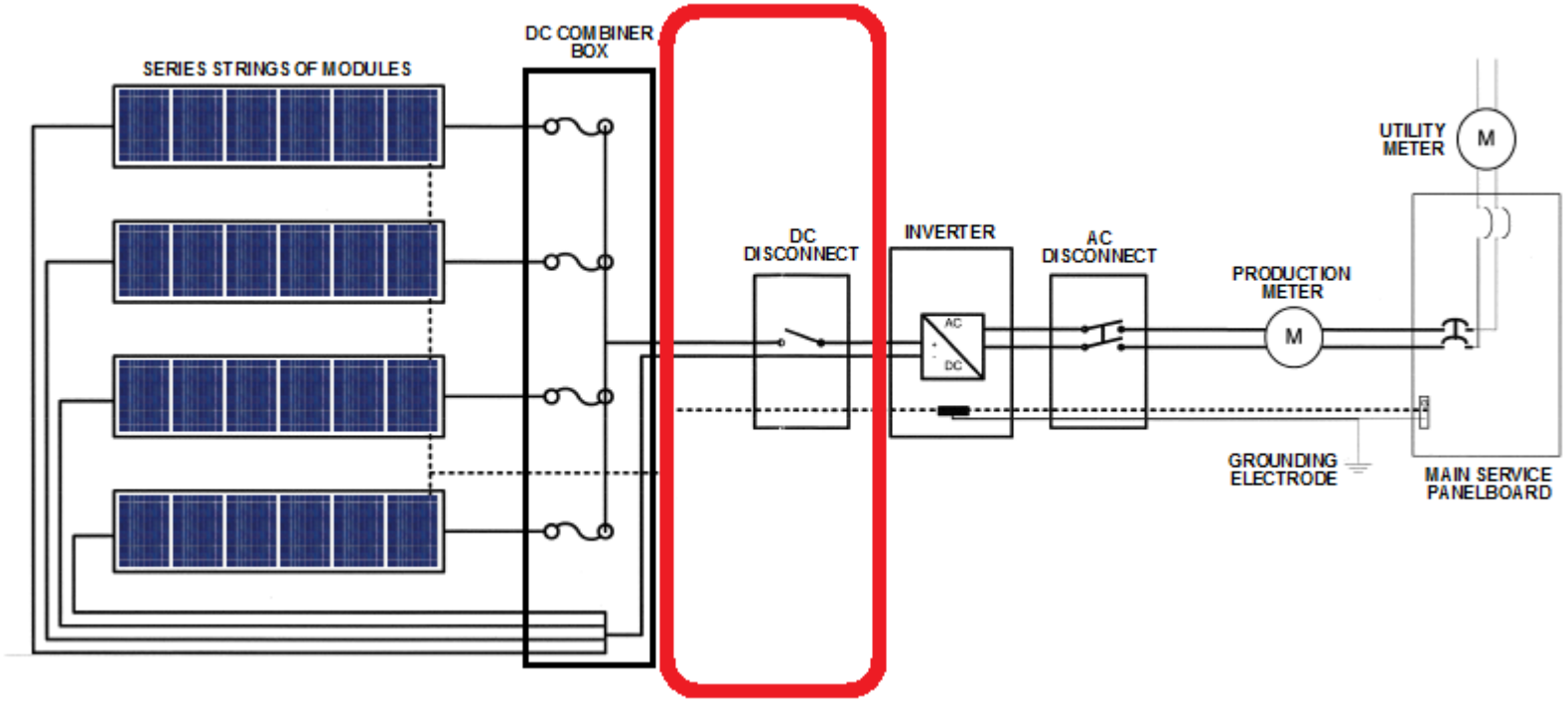
PV Output Violations



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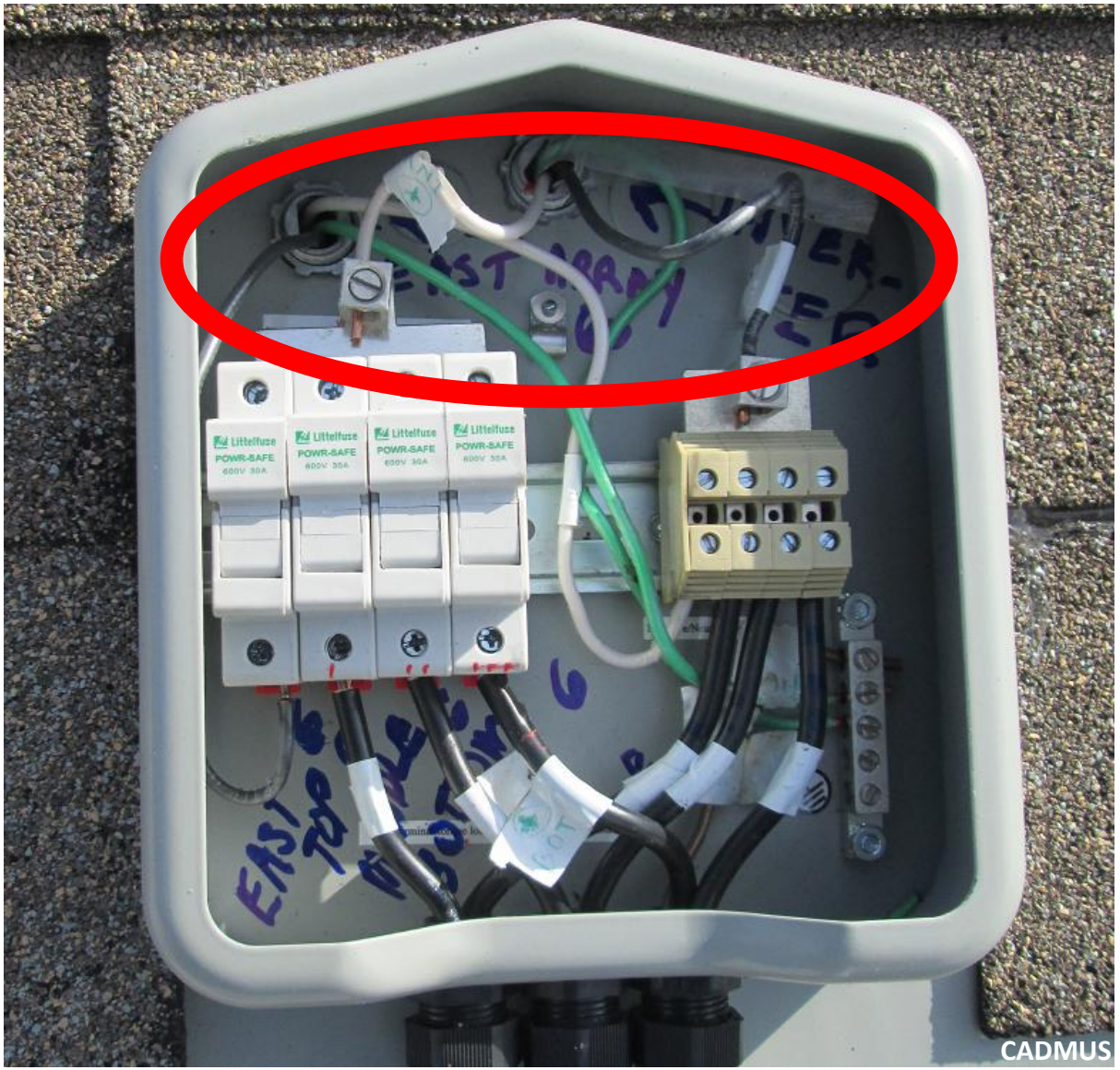
Common PV Output Violations

- Not properly sized for conditions
  - 690.8 calculations
  - 310.15 ampacity/temperature/conduit fill
- Not properly secured/supported
  - Article 338.10(B)(4)(b) → 334.30
- Not properly protected
  - Article 338.12(A)(1)



Undersized PV output conductors.

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Unprotected PV output conductors.

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The Right Way…

PV output conductors installed in conduit.

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The Right Way…

PV output conductors installed in conduit.

Common PV Output Violations

- Outdoor enclosures
  - Not grounded in accordance with 250.8(A)
  - Not installed “so as to prevent moisture from entering or accumulating…” in accordance with 314.15
  - Penetrations not sealed, as required by 300.7(A)

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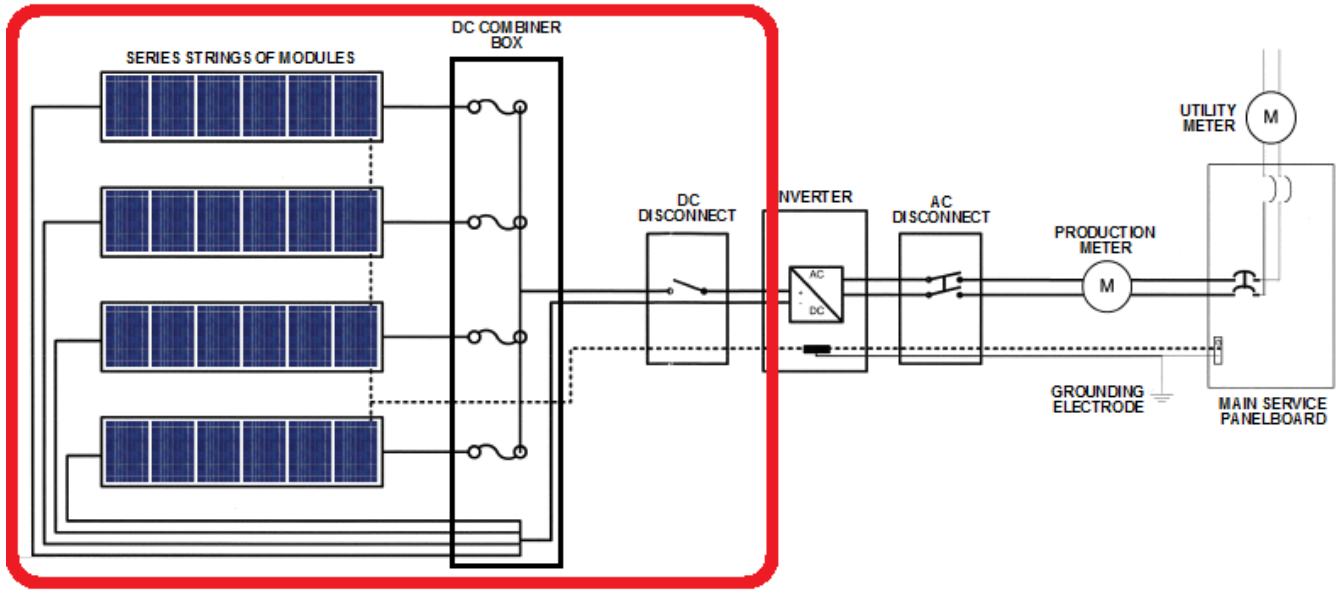
Enclosures must be installed "so as to prevent moisture from entering or accumulating…" in accordance with 314.15

Disconnect Interruption Rating
NEC Article 690.17(E)

- Must have an interruption rating sufficient for the maximum:
  - Circuit Voltage
  - Circuit Current
- …available at line terminals

DC AFCI Protection
NEC Article 690.11

- Adopted in MA for 2014
- All PV systems with DC operating at <u>80 Volts or greater</u>
  - Protected by listed “PV type” AFCI, or equivalent



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DC AFCI Protection
NEC Article 690.11

- All major brands ***now available***
  - Inverters
  - Combiner boxes
  - Micro inverters (not required)
    - Typically operate under 80 Volts DC
- ***Check the Model!***
- Ensure AFCI mode is enabled

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Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- PV system circuits on or in buildings shall include a rapid shutdown function:
  - 690.12(1) through (5)…

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About Article 690.12

- Intended to protect first responders
- Original proposal:
  - Disconnect power directly under array
    - Module-level shutdown
- Compromise:
  - Combiner-level shutdown

Rapid Shutdown of PV Systems on Buildings
NEC Article 690.12

- 690.12(1)
  - More than 10’ from an array
  - More than 5’ inside a building

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Rapid Shutdown of PV Systems on Buildings
NEC Article 690.12

- 690.12(2)
  - Within 10 seconds
    - Under 30 Volts
    - 240 Volt-Amps (Watts)
  - A typical module:
    - ~250 Watts
    - ~30 Volts
- 690.12(3)
  - Measured between:
    - Any 2 conductors
    - Any conductor and ground

Source: UL.com

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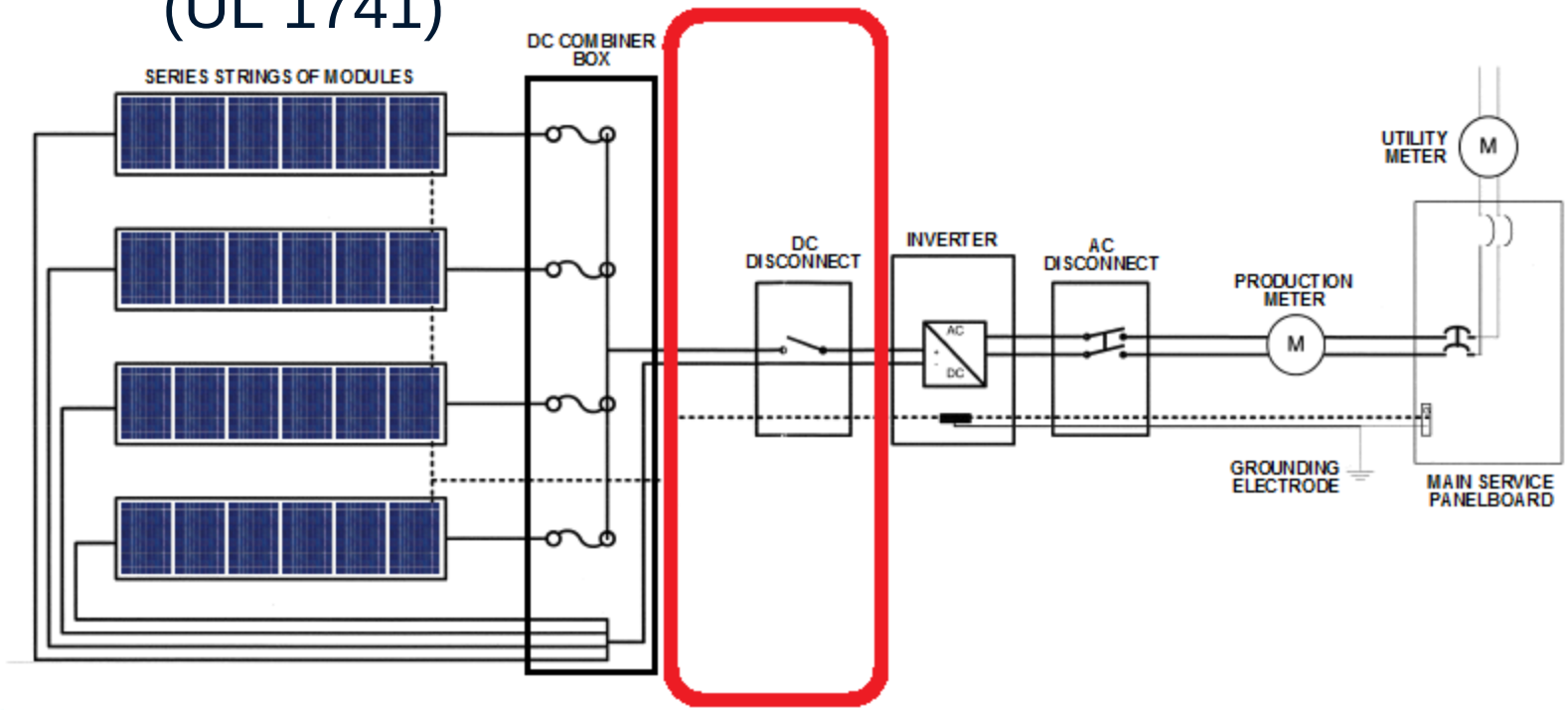
About Article 690.12

- Considerations:
  - Disconnect power within 10 seconds
  - Inverters can store a charge for up to 5 minutes (UL 1741)



Rapid Shutdown of PV Systems on Buildings
NEC Article 690.12

- 690.12(4)
  - Labeled per 690.56(C)
  - Minimum 3/8” CAPS

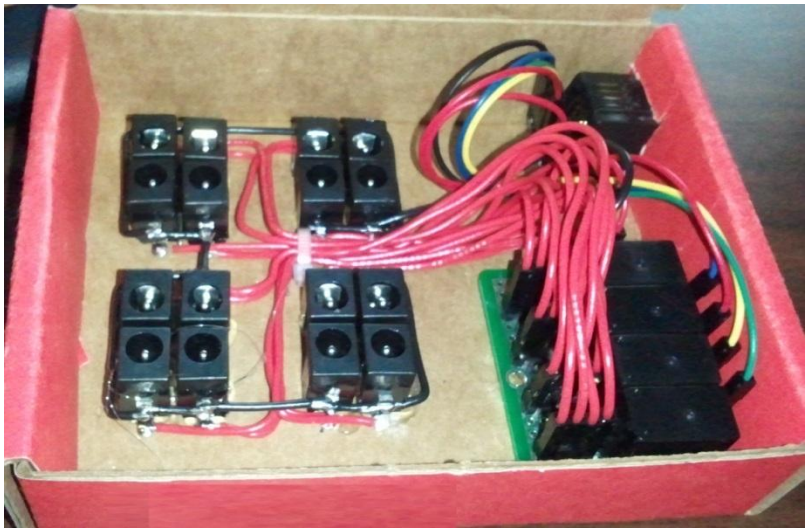
PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN

- White on Red
- Reflective

Rapid Shutdown of PV Systems on Buildings
NEC Article 690.12

- 690.12(5)
  - "Equipment that performs the rapid shutdown shall be listed and identified."
- MA Amendment (527 CMR 12):
  - *Equipment that performs the rapid shutdown shall be listed and identified. This provision shall be enforced as of January 1, 2017. In lieu of a comprehensive listing prior to this enforcement date, the individual components shall be listed as to their specific circuit functions, and the system as installed shall be performance tested in the presence of the authority having jurisdiction.*

http://www.mass.gov/eopss/docs/dfs/osfm/cmr/cmr-secured/527012.pdf



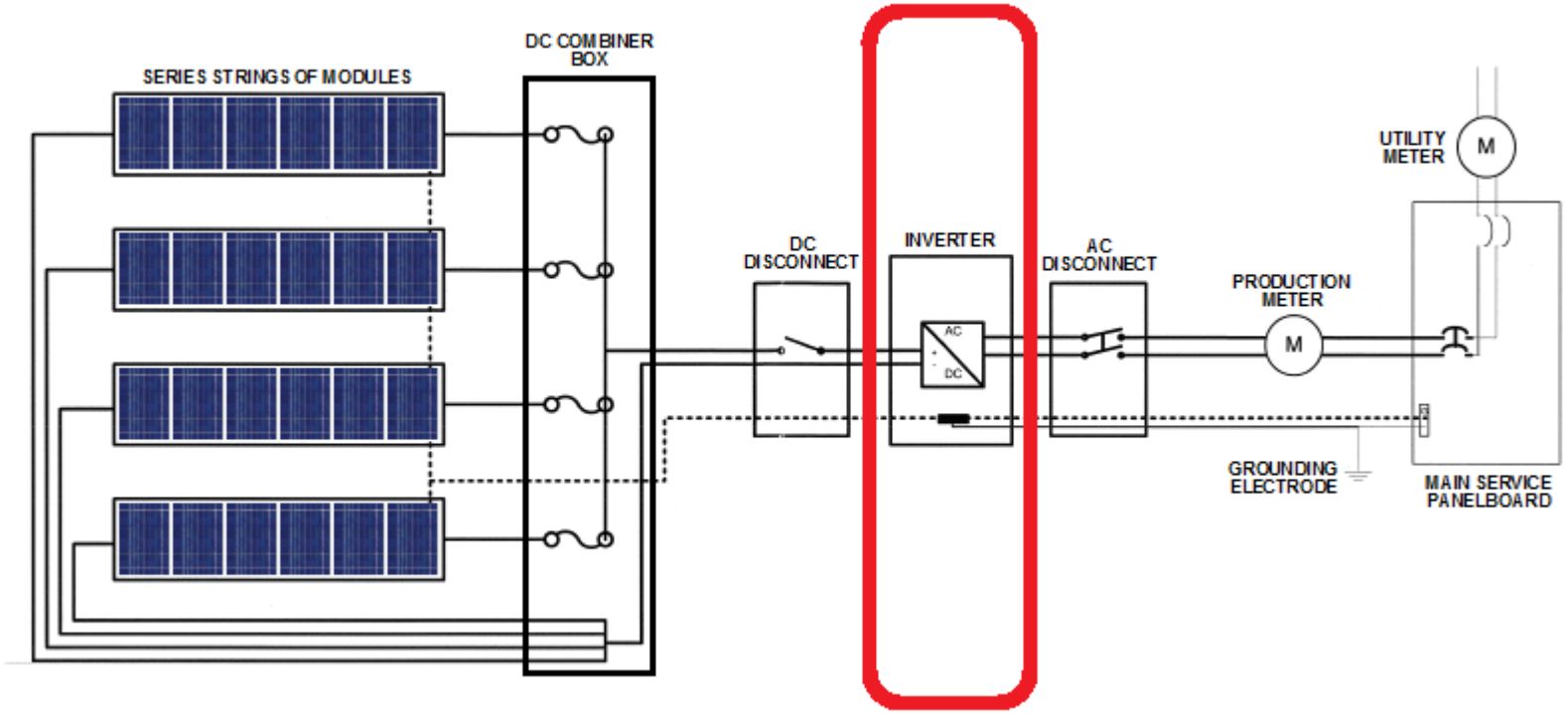
About Article 690.12

- Open-ended **gray areas**:
  - Location of “rapid shutdown initiation method”
  - Maximum number of switches
  - Type of building
    - Dwelling
    - Commercial

About Article 690.12

- What might comply:
  - Microinverters
  - AC modules
  - Exterior string inverters if either:
    - Located within 10 feet of array
    - Inside building within 5 feet
  - DC-to-DC Optimizers/Converters
    - May or may not depending on the model
  - “Contactor” or “Shunt Trip” Combiner Boxes/Disconnects
    - Must be listed for “Rapid Shutdown” as a system
      - See MA Amendment to 690.12(5)
- Many considerations & variations for full system compliance
  - Plans should be discussed with AHJ prior to installation

Inspecting the Inverter



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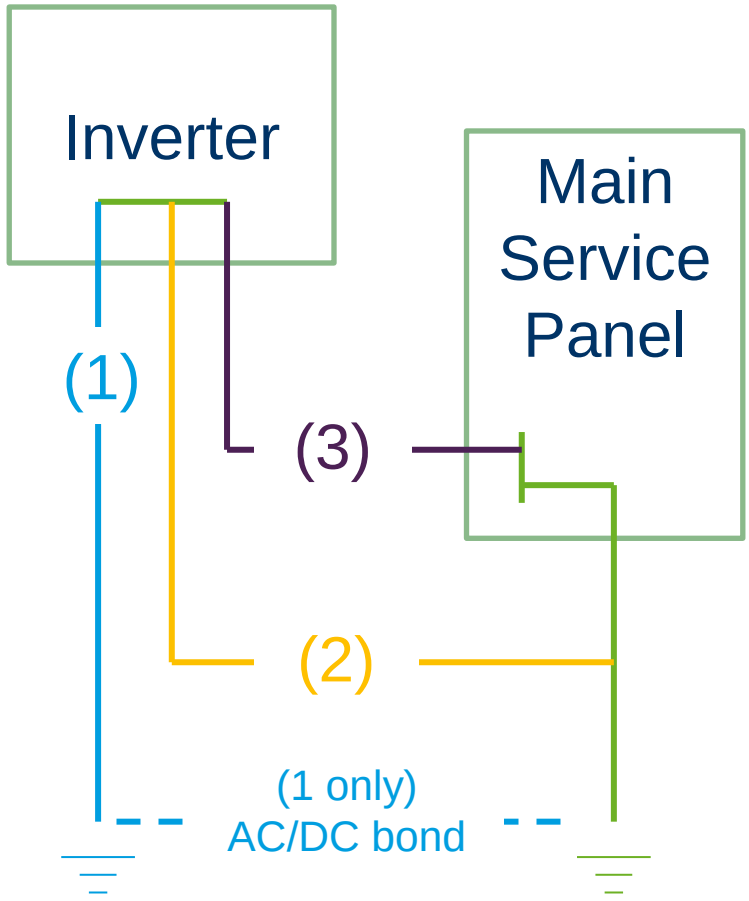
Understanding 690.47(C)

- ***DC Grounding Electrode Conductor (GEC)*** runs to an electrode or ground bar:
  1. A separate electrode installed for DC system grounding
  2. The electrode that serves for AC system grounding
  3. Main panel ground bar
     - May also serve as equipment grounding conductor
     - Method for transformerless inverters



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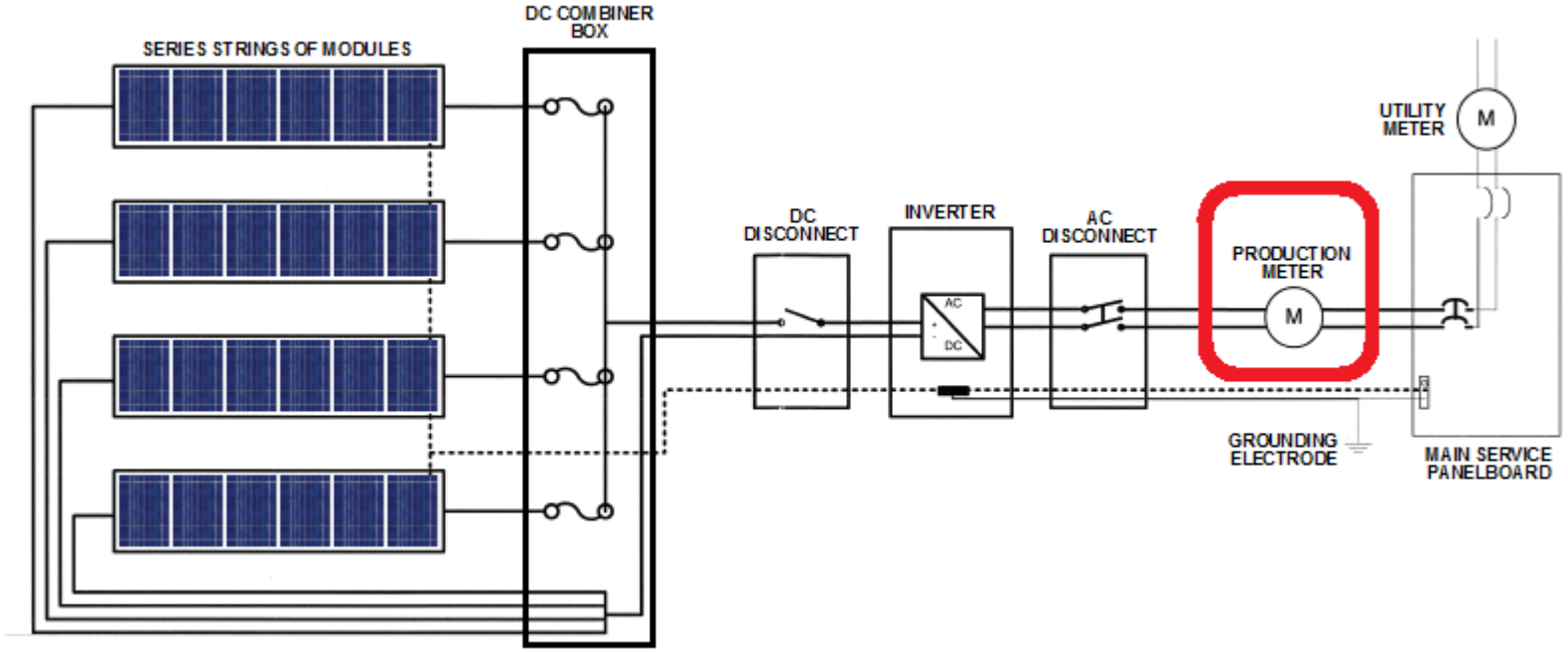
Production Meter Violations



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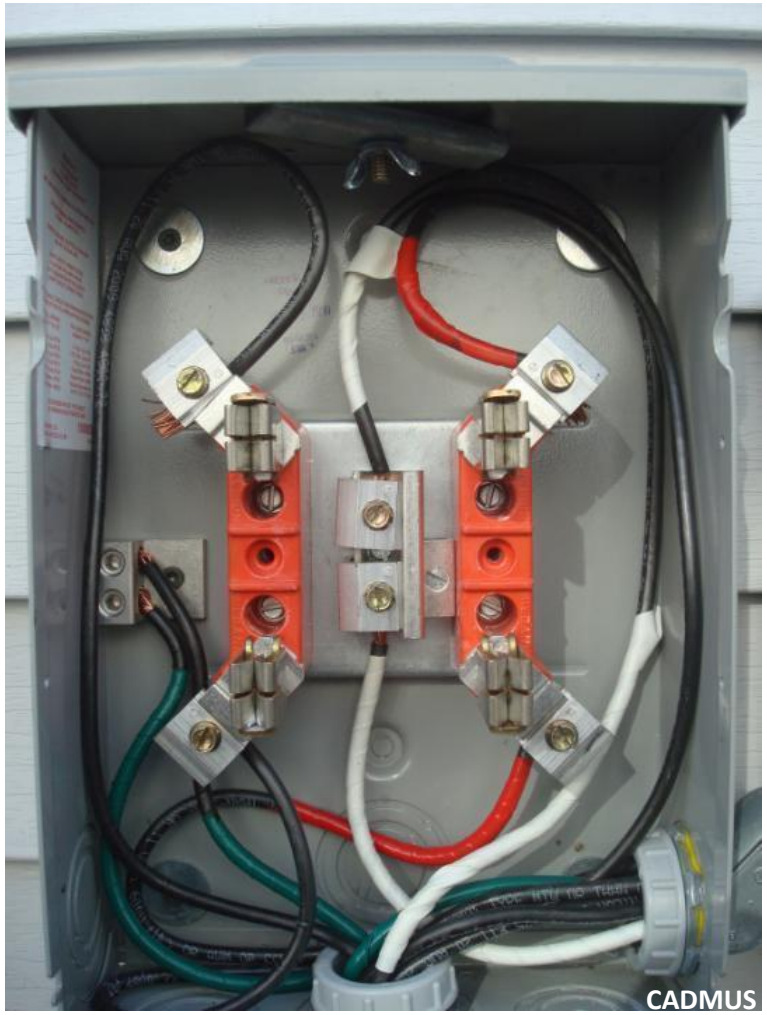
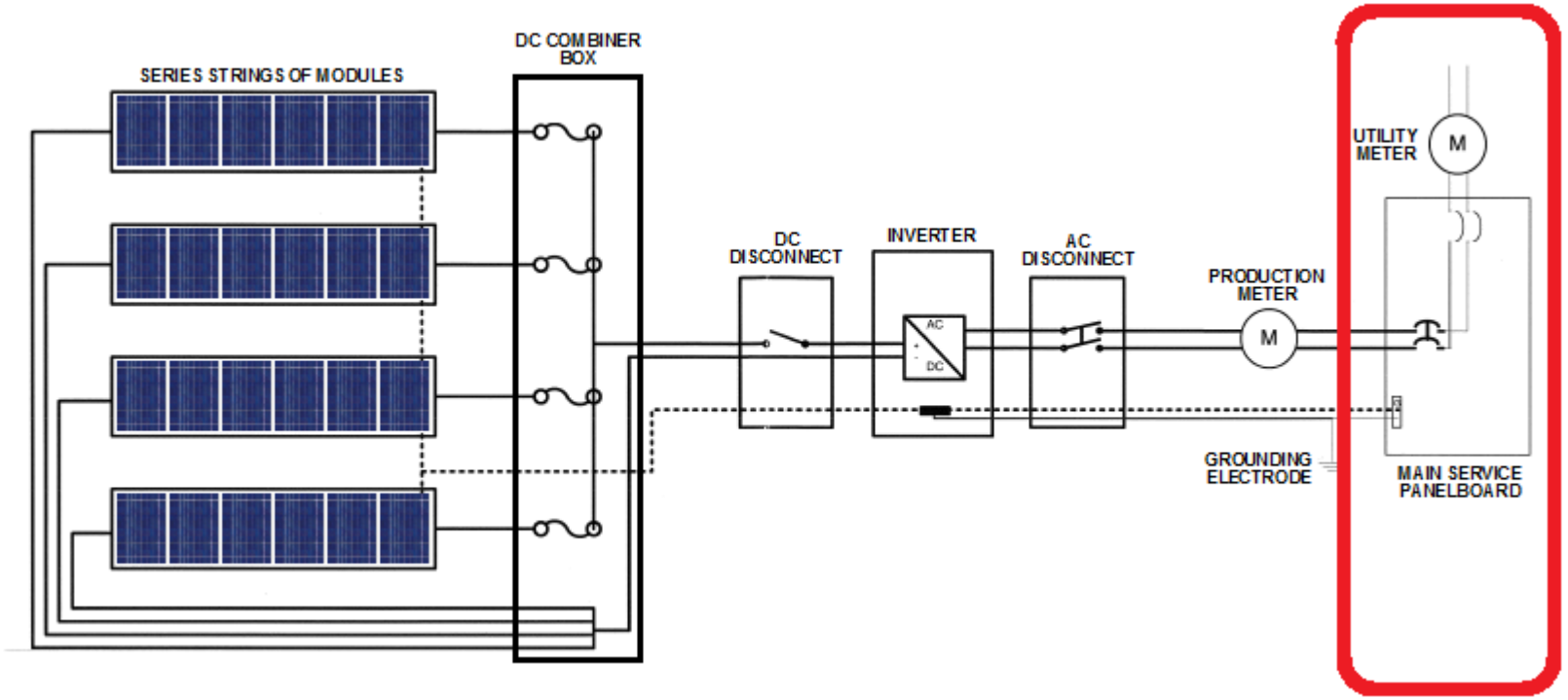
Production Meter Violations

- Article 250.24(A)(5)
  - Neutral conductor bonded to frame



PV Interconnection



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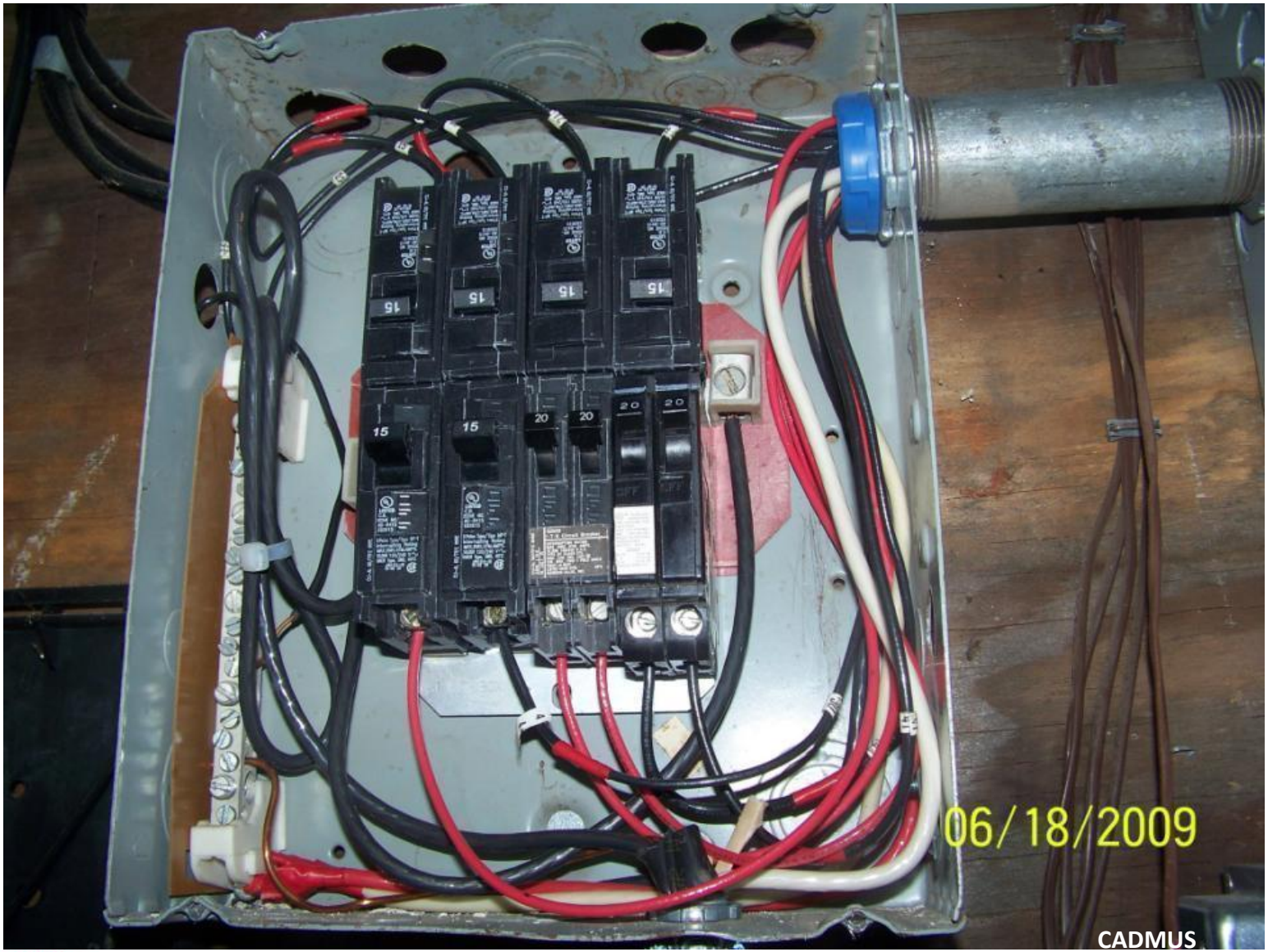

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Article 705.12
Formerly 690.64 (in 2008)

- 705.12 Point of Connection
  - Requirements for all interconnected electric power production sources
    - PV
    - Wind
    - Cogeneration
    - etc.
- 705.12(A) Supply Side
- 705.12(D) Load Side

Supply Side Interconnection
NEC Article 705.12(A)

- Interconnection on utility side of main service disconnect
- Sum of all overcurrent device ratings connected to power production systems shall not exceed rating of service
- “Second set” of service entrance conductors (Article 230)
- Utility conductors must be on line terminals
  - These remain energized when disconnect is opened (turned off)

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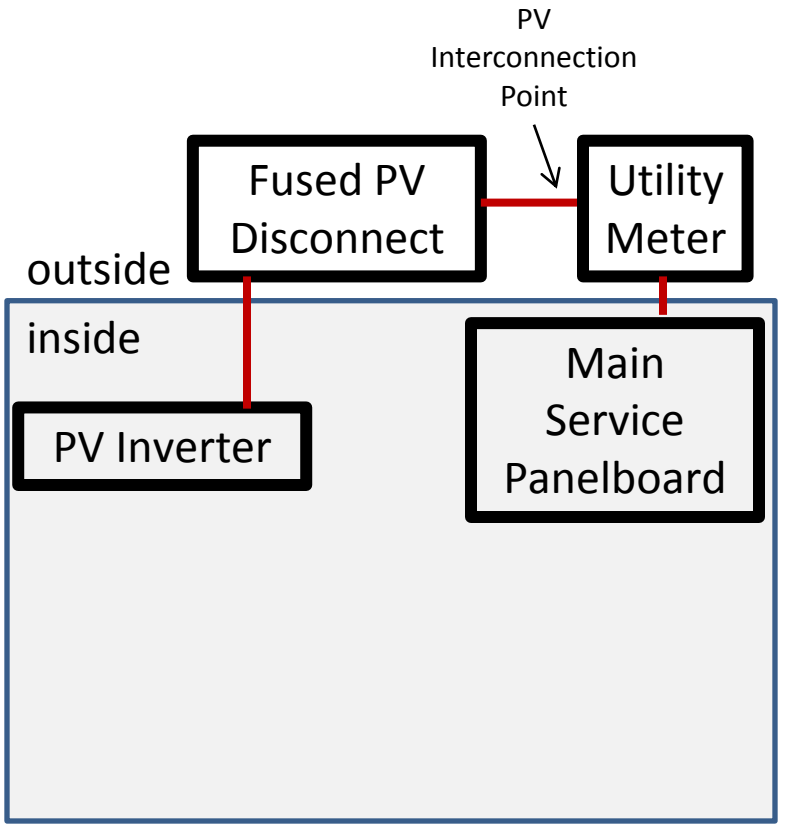
Supply Side Interconnection
Disconnect Grouping Example

- Interconnection near utility meter enclosure (load side)
  - Supply side of main breaker
- Fused PV disconnect located outside
- Panelboard and PV disconnect labeled per 705.10 and 705.12
- Article 690.56(B)
  - Requires plaque in this situation



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Load Side Interconnection

NEC Article 705.12(D)

- Most often at a back fed breaker in the main service panel
- Used at most residential PV systems
- Also used at commercial installations but can be problematic for larger PV systems

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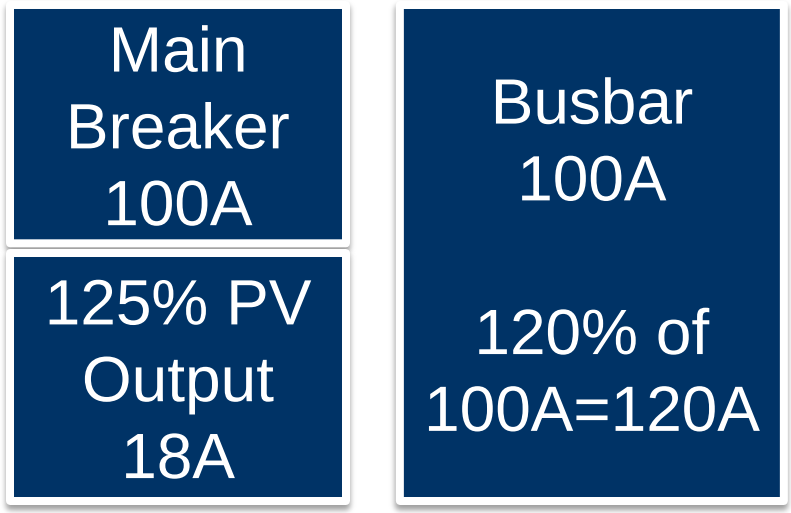
Load Side Interconnection
NEC Article 705.12(D)

- Key segments include:
  1. Interconnection shall be made at dedicated OCPD
  2. Feeders, Taps, Busbar Interconnection
  3. Equipment shall be marked to indicate presence of all sources
  6. AFCI protection for micro inverters

Bus or Conductor Ampere Rating – Busbars
NEC Article 705.12(D)(2)(3)(b)

- Option (B) “120% Rule”
- 120% of busbar ampacity not less than sum of:
  - Main OCPD
  - 125% of inverter current



Example:

Inverter current = 14.4A

14.4A x 125% = 18A

Main + PV = 118A

120% Busbar = 120A

118A feeds < 120A bus

- PV breaker must be at opposite end

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Wire Harness and Exposed Cable AFCI Protection
NEC Article 705.12(D)(6)

- Intended for micro inverters
- Wire harness or cable output circuit rated:
  - 240 Volts
  - 30 Amps or less
- Not installed in a raceway, listed AFCI protection
  - Circuit breaker, suitable for backfeed

Wire Harness and Exposed Cable AFCI Protection
NEC Article 705.12(D)(6)

- Recommendation from the SEIA Codes and Standards Working Group and SolarABCs (http://www.solarabcs.org/) PV Industry Forum to remove 705.12(D)(6) from the 2017 Code. Why?
  - No suitable devices are widely available on the market
    - Suitable for backfeed
    - 3-pole, 3-phase devices
  - Requirements are not aligned with how Arc-Fault protection as implemented for ac premises wiring 210.12
    - Single phase 120 V circuits
    - Convenience outlets and zip cords
    - Outdoor circuits are exempted
    - Fire classified roof surface with PV modules evaluated for ignition and flame spread
  - Safety standards do not adequately cover PV applications (UL 1699)
    - Backfeed
    - 3-phase circuits
    - Nuisance tripping

Stand-Alone System Clarification

NEC Article 690.10(E)

- Plug-in type back-fed circuit breakers shall be secured in accordance with 408.36(D)
- Multimode inverter output in stand-alone systems
- Does not apply for utility-interactive systems
  - See 705.12(D)(5)

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QUESTIONS??

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Matt Piantedosi at matt.piantedosi@cadmusgroup.com
phone: (617) 673-7102

http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/solar-permitting-and-structural-review-rsc2.html

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